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OF MECHANICAL CONNECTIONS

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RECOMMENDED PROCEDURES FOR CONDUCTING PULL-OVER, PULL-OUT AND SINGLE-SHEAR TESTS OF MECHANICAL CONNECTIONS

Second Progress Report

by

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Project Directors

DEVELOPMENT OF COMPREHENSIVE TEST
PROCEDURES FOR CONNECTIONS IN COLD-FORMED
STEEL AND APPROPRIATE EVALUATION METHODS

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RECOMMENDED PROCEDURES FOR CONDUCTING PULL-OVER, PULL-OUT AND SINGLE-SHEAR TESTS OF MECHANICAL CONNECTIONS

1. SCOPE

1.1 These methods cover procedures and definitions for the mechanical testing of joints formed by connecting a cold-formed steel member to a cold-formed or hot-rolled steel member with one or more mechanical fasteners. The purpose of these procedures is the determination of the load capacities of the joints so formed.

1.2 The term "mechanical fastener" or "fastener" shall be defined as any mechanical device used in the connection of two or more members, inclusive of such devices as bolts, tapping screws and rivets but exclusive of welds and adhesives.

1.3 The following mechanical tests are described:

	Sections
Pull-Over	4 - 11
Pull-Out	12 - 19
Single-Shear (Lap Joint)	20 - 26
Single-Shear (Simulated Diaphragm Action)	27 - 34

2. GENERAL PROCEDURES AND PRECAUTIONS

2.1 All fastener holes in test specimens shall be of an identical diameter to those employed in the actual application. Fastener holes shall be formed using equipment identical, or as nearly similar as possible, to that used in the actual application.[1]

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[1] Recommended hole diameters are available from some fastener manufacturers for specific products. Also refer to the complete ANSI B18.6.4 standard available from ASME for thread-forming and thread-cutting screws.

2.2 All fasteners in test specimens shall be tightened to an amount of torque equal to that employed in the actual application. Fastener driving and/or torqueing devices shall be identical, or as nearly similar as possible, to those used in the actual application, with the same procedures employed in both instances.

2.3 Improper machining or preparation of test specimens may give erroneous results. Care should be taken to assure good workmanship in specimen preparation. Improperly prepared specimens should be discarded and other specimens substituted.

2.4 Should a test specimen fail improperly due to faulty arrangements, such as failure of the testing equipment or improper specimen installation, it may be discarded and another specimen taken.

3. DESIRABILITY OF PROTOTYPE TESTING

3.1 The large inventory of mechanical fasteners of various types, sizes and mechanical properties in existence, together with the innovations possible in the design of connections, may create situations where the tests described herein are less than adequate to fully evaluate the connection under consideration. Thus it is recommended that whenever practicable a full-scale prototype of the proposed connection be tested. Such testing is especially important when a unique design or special material is proposed. In addition, such testing will afford the user a firm idea of the correlation between the results of the tests contained herein and the actual application.

PULL-OVER TEST

4. DEFINITION AND DESCRIPTION

4.1 A pull-over failure shall be defined as a connection failure caused by the fastener head assembly pulling through the material immediately beneath it, or conversely, the connected material pulling over the fastener head assembly. This type of failure is normally associated with relatively thin panel sections connected to heavier members and subjected to uplift or other loading which produces tension in the fastener.

4.2 The Pull-Over Test is a test designed to determine the ultimate load capacity of a connection subjected to uplift where the mode of failure is the extraction of the material from under the head assembly of the fastener. A fastener is driven through an 8 in. square test specimen into a loading channel. The specimen is attached to a support with four 1/2 in. bolts and the loading channel is connected to a loading arm. The entire assembly is then placed in a tension testing machine, as shown in Figure 1, and the force required to pull the fastener head assembly through the specimen is measured.

5. TEST LIMITATIONS

5.1 This test is believed to be a reasonable simulation of the behavior of most connections subjected to uplift where pull-over is the mode of failure. It can be readily modified to accomodate many specimen shapes and connections and in some instances can utilize all components of the actual application.

5.2 Use of the test fixture described herein shall be limited to test specimens whose thickness is less than or equal to 0.10 in. Specimens with a thickness greater than this limit may be tested in a similar fixture with suitably increased dimensions.

6. TEST SPECIMEN PARAMETERS

6.1 Flat-Shaped Specimens. The test specimen parameters to be used for flat-shaped specimens tested in pull-over are given in Figure 2. The governing parameter is that the 9/16 in. diameter holes be centered relative to the fastener location on a 6 in. square.

6.2 Corrugated (Ribbed) Specimens. The test specimen parameters to be used for corrugated specimens are identical to those for flat-shaped specimens, namely 9/16 in. diameter holes on a 6 in. square centered with respect to the fastener location. The fastener location relative to the corrugations shall be identical to the location used in the actual application.

6.3 The material employed in this test shall be identical to that used in the actual application. Surface treatment, if any, shall remain undisturbed.

7. PREPARATION OF TEST SPECIMEN

7.1 Test specimens may be removed from the parent stock by any suitable means, including cutting and shearing, that does not affect the material properties in the vicinity of the fastener location.

7.2 The four 9/16 in. diameter holes shall be formed in the test specimen by either drilling or cutting with a hole saw. If desired, test specimens may be stacked, clamped and drilled altogether. Rough edges incurred in this process shall be removed by a suitable means to leave a smooth, flat surface.

7.3 The fastener hole shall be formed in the test specimen in a location relative to any ribs or corrugations that is identical to that used in the actual application, employing the same diameter and forming technique used in the actual application.

8. TESTING APPARATUS AND EQUIPMENT

8.1 Test Fixture. The basic test fixture consists of an 8 in. square base plate with two 1 in. square bars welded onto it. A rod is attached to the center of the base plate to permit placement in a tension testing machine and the square bars are tapped for 1/2 in. bolts to enable attachment of the test specimen. The test fixture is completed with a loading channel and a loading arm to transmit the load from the testing machine to the channel. Figure 1 presents an elevation view of the test fixture with a test specimen in place.

8.2 Test Fixture Components. The following are the descriptions of the various component parts of the test fixture.

8.2.1 Base Plate. A steel plate 8 in. square and a minimum of 3/8 in. thick, drilled and tapped at its center to accomodate a 1/2 in. diameter threaded rod. To this plate are welded two steel rectangular bars 8 in. long and 1 in. square in cross-section with their longitudinal axes 6 in. apart. Care shall be taken in welding to assure that the components remain plane. Each bar shall have two drilled and threaded holes for 1/2 in. bolts, located 6 in. apart and centered with respect to both axes. A drawing of the base plate assembly is presented as Figure 3.

8.2.2 Loading Channel. A channel formed by welding together three steel plates as shown in Figure 4. The plates are a minimum of 3/8 in. thick and are welded in a manner that leaves the sections plane. The thickness requirement may be waived if the grip length of the test fastener necessitates a thinner channel base plate. A hole is drilled and tapped at the center of the base of the channel to mate with the test fastener being employed. A piece of the actual member to which the connection is to be made may be used if desired, provided that a piece of roughly similar dimensions to the loading channel can be obtained from it.

8.2.3 Loading Arm. A steel rectangular bar 8 in. long and 1 in. by 2 in. in cross-section, drilled and tapped at one end to accomodate a 1/2 in. threaded rod and drilled at the other for a 1/2 in. diameter pin. A drawing of the loading arm is presented as Figure 5.

8.2.4 Miscellaneous Items. In addition to the 1/2 in. diameter pin and 1/2 in.bolts and washers, two angle sections and as many as four spacer sleeves may be required. The angle sections are 8 in. long and a minimum of 1/8 in. thick, slotted with two 9/16 in. slots as shown in Figure 6. The spacer sleeves are tubular sections with an inside diameter slightly larger than 1/2 in. and a length determined by the configuration of the test specimen employed.

8.3 Loading System. The loading system to be employed in this test is a tension testing machine. This machine shall be maintained in good operating condition, used only in the proper loading range, and calibrated periodically in accordance with the latest revision of ASTM Methods E4, Verification of Testing Machines. Both upper and lower gripping or holding devices of the testing machine shall be suitable for round sections.

8.4 Displacement Measurement. A displacement measurement, if desired, can be obtained by suitably placing a dial gage between the loading arm and base plate using such magnetic or mechanical holding devices as may be deemed necessary.

9. ASSEMBLY OF TEST COMPONENTS

9.1 Fastener Installation. The fastener shall be installed through the test specimen into the loading channel employing the same driving technique and equipment as used in the actual application. If filler material such as insulation is used between the section and main members in the actual application, the same material of equal thickness shall be used between the test specimen and the loading channel. Tightening torque affects the strength of a connection subjected to uplift and thus it is imperative that the tightening torque used on the test specimen be identical, or as nearly similar as practicable, to that employed in the actual application. If necessary or appropriate, properly calibrated devices shall be used to assure compliance with this requirement.

9.2 Specimen Installation. The test specimen shall be installed on the base plate with four 1/2 in. diameter high strength bolts. In all cases the bolts shall be of such a length to assure a minimum of 1/2 in. thread engagement in the base plate, shall employ a washer immediately under the head of the bolt, and shall be tightened to approximately 20 ft.-lbs. of torque.

9.2.1 Flat-Shaped Specimens. Flat-shaped specimens, connected to the loading channel in accordance with the provisions of paragraph 9.1, shall be installed directly onto the base plate with the four 1/2 in. bolts. Care shall be exercised to assure proper alignment of the base plate and test specimen.

9.2.2 Corrugated (Ribbed) Specimens. If the test specimen has sufficient stiffness in the direction perpendicular to the corrugations to resist excessive deformation, or deformation under load which would alter the fastener hole geometry, it shall be installed in the manner given for flat-shaped specimens in the preceding paragraph provided that the four 9/16 in. holes lie in the same plane. This situation is depicted in Figure 7. If the 9/16 in. holes lie in different planes appropriate length spacer sleeves shall be employed as shown in Figure 8. If sleeves are employed, a washer shall be used between the sleeve and the test specimen. Some distortion of the corrugations is permitted to assure proper tightening of the bolts.

9.2.2.1 If the corrugated test specimen has insufficient stiffness to resist excessive deformations it shall be installed on the base plate with the two slotted angle sections and appropriate length spacer sleeves in a manner similar to that shown in Figure 9. The angle sections shall be positioned such that 45 degree lines may be drawn from the fastener location to the points defined by the intersection of the angle section and the rib most distant from the fastener, as shown in Figure 10. If spacer sleeves are employed, a washer shall be used between the sleeve and the test specimen.

10. TEST PROCEDURE

10.1 Loading. The base plate assembly, with the test specimen and loading channel attached in accordance with the provisions of Section 9, shall be placed in the upper gripping or holding device of the testing machine. The loading arm shall then be attached to the loading channel with a 1/2 in. diameter pin and secured in the lower gripping or holding device of the testing machine. The final configuration of the complete assemblage is shown in Figure 1. Care shall be taken to assure that the centers of the grips are in alignment, insofar as practicable, with the axis of the fixture of the beginning and during the test.

10.2 Measurement of Relative Displacement. Relative displacement measurements, if desired, may be obtained by suitably attaching a dial gage of a desired accuracy between some point on the loading arm or channel and the base plate of the test fixture with the complete assembly in place in the testing machine.

10.3 Speed of Testing. The speed of testing shall not be greater than that at which load and relative displacement readings can be made accurately. In addition, up to the vicinity of the ultimate load the speed of testing shall not exceed either a 0.02 in. per min. rate of separation of the two heads of the testing machine under load or a 100 lb. per min. rate of load, whichever produces the greater rate of separation of the two loads of the testing machine under load. In the vicinity of the ultimate load the loading shall be conducted in increments, with the size of each increment determined by the accuracy desired. The load shall be maintained at each increment for a minimum period of one minute before proceeding to the next increment.

11. EVALUATION OF TEST RESULTS

11.1 The ultimate strength of the connection in pull-over shall be taken as the value of the ultimate load attained in this test.

11.2 The load-deformation curve of the connection in pull-over shall be the load-deformation curve obtained from this test. Such a curve, if obtained, should be used with caution since actual deformation will be governed by support and boundary conditions.

PULL-OUT TEST

12. DEFINITION AND DESCRIPTION

12.1 A pull-out failure shall be defined as a connection failure caused by the threaded portion of the fastener stripping out of the material in which thread engagement existed. This type of failure is normally associated with fasteners which form their own mating threads in the material into which they are driven (self-tapping fasteners).

12.2 The Pull-Out Test is a test designed to determine the ultimate load capacity of a connection subjected to uplift where the mode of failure is the extraction of the fastener from the material into which it was driven. A fastener is driven through a loading channel into an 8 in. square test specimen. The specimen is attached to a support with four 1/2 in. bolts and the loading channel is connected to a loading arm. The entire assembly is then placed in a tension testing machine, as shown in Figure 11, and the force required to extract the fastener from the specimen is measured.

13. TEST LIMITATIONS

13.1 This test is a good simulation of the behavior of a connection subjected to uplift where pull-out is the mode of failure. It can be readily modified to accomodate most connections and specimen configurations, and with additional modification may be used to approximate eccentric pull-out behavior. This test procedure, however, covers only pull-out failures involving no eccentricity.

13.2 Use of the test fixture described herein shall be limited to test specimens whose thickness is less than or equal to 0.20 in. Specimens with a thickness greater than this limit may be tested in a similar fixture with suitably increased dimensions.

14. TEST SPECIMEN PARAMETERS

14.1 The test specimen parameters for the Pull-Out Test are identical to those for the Pull-Over Test for flat-shaped and corrugated (ribbed) specimens.

14.1.1 Flat-Shaped Specimens. The test specimen parameters to be used for flat-shaped specimens tested in pull-out are given in Figure 2. The governing parameter is that the 9/16 in. diameter holes be centered relative to the fastener location on a 6 in. square.

14.1.2 Corrugated (Ribbed) Specimens. The test specimen parameters to be used for corrugated specimens are identical to those for flat-shaped specimens, namely 9/16 in. diameter holes on a 6 in. square centered with respect to the fastener location. The fastener location relative to the corrugations shall be identical to the location used in the actual application.

14.1.3 Formed Specimens. Formed specimens, e.g. channel, zee or rectangular sections, are to be a minimum of 8 in. in length and identical to that used in the actual application.

14.2 The material employed in this test shall be identical to that used in the actual application. Surface treatment, if any, shall remain undisturbed.

15. PREPARATION OF TEST SPECIMEN

15.1 Test specimens may be removed from the parent stock by any suitable means, including cutting and shearing, that does not affect the material properties in the vicinity of the fastener location.

15.2 The four 9/16 in. holes shall be formed in test specimens that are either flat or corrugated by either drilling or cutting with a hole saw. If desired, test specimens may be stacked, clamped and drilled altogether. Rough edges incurred in this process shall be removed by a suitable means to leave a smooth, flat surface.

15.3 The fastener hole shall be formed in the test specimen in a location relative to any ribs or corrugations that is identical to that used in the actual application, employing the same diameter and forming technique used in the actual application.

16. TESTING APPARATUS AND EQUIPMENT

16.1 Test Fixture. The Pull-Out Test employs the same test fixture used in the Pull-Over Test, except that the loading channel components shall have a minimum thickness of 1/4 in. and the hole in the loading channel shall be slightly larger than the diameter of the fastener used. A description of the test fixture and its assembly is presented in Sections 8.1 and 8.2.

16.2 Loading System. The loading system to be employed in this test is a tension testing machine. This machine shall be maintained in good operating condition, used only in the proper loading range, and calibrated periodically in accordance with the latest revision of ASTM Methods E4, Verification of Testing Machines. Both upper and lower gripping or holding devices of the testing machine shall be suitable for round sections.

16.3 Displacement Measurement. A displacement measurement, if desired, can be obtained by suitably placing a dial gage between the loading arm and base plate using such magnetic or mechanical holding devices as may be deemed necessary.

17. ASSEMBLY OF TEST COMPONENTS

17.1 Fastener Installation. The fastener shall be installed through the loading channel into the test specimen employing the same driving technique and equipment as used in the actual application. Tightening torque materially affects the strength of a connection subjected to uplift and thus it is imperative that the tightening torque used on the test specimen be identical, or as nearly similar as practicable, to that employed in the actual application. If necessary or appropriate, properly calibrated devices shall be used to assure compliance with this requirement.

17.2 Specimen Installation. The test specimen shall be installed on the base plate with four 1/2 in. diameter high strength bolts. In all cases the bolts shall be of such a length to assure a minimum of 1/2 in. thread engagement in the base plate and shall employ a washer immediately under the head of the bolt.

17.2.1 Flat-Shaped Specimens. Flat-shaped specimens, connected to the loading channel in accordance with the provisions of paragraph 17.1, shall be installed directly onto the base plate with the four 1/2 in. bolts. Care shall be exercised to assure proper alignment of the base plate and test specimen, and the bolts shall be tightened to approximately 20 ft.-lbs. of torque.

17.2.2 Corrugated (Ribbed) Specimens. If the test specimen has sufficient stiffness in the direction perpendicular to the corrugations to resist excessive deformation, or deformation under load which would alter the fastener hole geometry, it shall be installed in the manner given for flat-shaped specimens in the preceding paragraph provided that the four 9/16 in. holes lie in the same plane. This situation is depicted in Figure 7. If the 9/16 in. holes lie in different planes appropriate length spacer sleeves shall be employed as shown in Figure 8. If sleeves are employed, a washer shall be used between the sleeve and the test specimen. The bolts shall be tightened to approximately 20 ft.-lbs. of torque, with some distortion of the corrugations permitted to assure proper tightening.

17.2.2.1 If the corrugated test specimen has insufficient stiffness to resist excessive deformations it shall be installed on the base plate with two suitable angle sections and appropriate length spacer sleeves in a manner similar to that shown in Figure 9. The 1/2 in. bolts shall be tightened to approximately 20 ft.-lbs. of torque.

17.2.3 Formed Specimens. Formed specimens shall be installed on the base plate by using two suitable angle sections as shown in Figure 12. Care shall be exercised to assure that the test fastener is centered with respect to both axes of the base plate. The bolts shall be sufficiently tightened to assure that the test specimen is securely clamped without being distorted.

18. TEST PROCEDURE

18.1 Loading. The base plate assembly, with the test specimen and loading channel attached in accordance with the provisions of Section 17, shall be placed in the upper gripping or holding device of the testing machine. The loading arm shall then be attached to the loading channel with a 1/2 in. diameter pin and secured in the lower gripping or holding device of the testing machine. The final configuration of the complete assemblage is shown in Figure 11. Care shall be taken to assure that the centers of the grips are in alignment, insofar as practicable, with the axis of the fixture at the beginning and during the test.

18.2 Measurement of Relative Displacement. Relative displacement measurements, if desired, may be obtained by suitably attaching a dial gage of a desired accuracy between some point on the loading arm or channel and the base plate of the test fixture with the complete assembly in place in the testing machine.

18.3 Speed of Testing. The speed of testing shall not be greater than that at which load and relative displacement readings can be made accurately. In addition, the speed of testing shall not exceed either a 0.02 in per min. rate of separation of the two heads of the testing machine under load or a 100 lb. per min. rate of loading, whichever produces the greater rate of separation of the two heads of the testing machine under load.

19. EVALUATION OF TEST RESULTS

19.1 The ultimate strength of the connection in pull-out shall be taken as the value of the ultimate load attained in this test.

19.2 The load-deformation curve of the connection in pull-out shall be the load-deformation curve obtained from the test. Such a curve, if obtained, should be used with caution since actual deformation will be governed by support and boundary conditions.

SINGLE-SHEAR (LAP JOINT) TEST

20. DEFINITION AND DESCRIPTION

20.1 The Single-Shear (Lap Joint) Test is a common and simple test designed to determine the shear capacity of a simple overlap joint. Two straps, each of a desired thickness, are joined together with two fasteners located parallel to the direction of force. The assemblage is then placed in a tension testing machine and the ultimate strength of the connection is measured.

21. TEST LIMITATIONS

21.1 Some eccentricity in the transfer of force across the joint together with some out-of-plane distortions combine to make this test less than ideal for some shear transfer simulations, notably the simulation of diaphragm action. This test is considered adequate for many situations, however. If increased accuracy in simulating diaphragm action is desired or deemed necessary the more complex Single-Shear (Simulated Diaphragm Action) Test should be performed.

22. TEST SPECIMEN PARAMETERS

22.1 Figure 13 shows the typical test specimen configuration to be employed in the Single-Shear (Lap Joint) Test. The following are the values to be used for the parameters designated in the figure:

22.1.1 Edge distance e. If edge failures are not to be considered the edge distance e shall be taken as the greater of 1 in. or 4d, where d is the fastener diameter. If edge failures are to be considered the edge distance e shall be the value used in the actual application.

22.1.2 Fastener spacing s. The fastener spacing s shall be taken as the greater of 2 in. or 8d, where d is the fastener diameter.

22.1.3 Specimen width b. The specimen width b shall be taken as the greater of 2 in. or 8d, where d is the fastener diameter.

22.1.4 Specimen strap length L. The length L of each component strap of the specimen shall be at least the greater of 15 in. or 5 (e + s). Strap lengths longer than this minimum are desirable as they tend to decrease the eccentricity of the joint tested.

22.1.5 Specimen thicknesses t_1 and t_2. The specimen thicknesses t_1 and t_2 shall be identical to, and in the same position relative to the head of the fastener as, the actual application.

22.2 If either one or both of the component straps of the test specimen are not flat-shaped, or have a reasonably flat area at least as wide as the specimen width b, the specimen width specification in paragraph 22.1.3 does not apply and the actual section configuration, together with flanges, if any, shall be used. In this case approximately 4 in. at the end of such a strap shall be appropriately deformed, by either cutting or bending or both, to form a surface suitable for gripping.

22.3 The material employed in this test shall be identical to that used in the actual application. Surface treatment, if any, shall remain undisturbed except for an approximate 4 in. length at the end of each component strap which may be altered by any suitable means to provide for a more slip resistant grip.

23. PREPARATION OF TEST SPECIMEN

23.1 Component straps for the test may be removed from the parent stock by any suitable means, including mechanical cutting and shearing, that does not measurably effect the material properties at a distance of one fastener diameter from the edge. Edge roughness incurred in this process that might prevent the component straps from mating completely shall be removed by a suitable means, preferably filing.

23.2 If the actual application is to involve the forming of holes in both component parts of the joint simultaneously, the two component straps of the test specimen shall be well aligned and suitably clamped in the final specimen configuration. Care shall be exercised to assure proper alignment and thus the elimination of bending in the plane of the specimen at the joint. The fastener holes shall be formed with the specimen in this clamped position, employing the same hole diameters and forming techniques as used in the actual application.

23.3 If the actual application is to involve the forming of holes in each component part of the joint individually, such holes shall be formed in each component strap of the test specimen employing the same hole diameters and forming techniques used in the actual application. Additional care must be exercised to assure that both component parts of the test specimen will be well aligned when mated and thus avoid bending in the plane of the specimen at the joint.

23.4 The two fasteners shall be installed from the same side of the test specimen with both component straps carefully mated and clamped together, employing a technique identical to that used in the actual application. In all circumstances the tightening torque shall be identical, or as nearly similar as practicable, to that employed in the actual application. If necessary or appropriate, suitably calibrated devices shall be used to assure fulfillment of this condition.

23.5 Approximately the final 4 in. of length at each end of the test specimen shall have the surface on both sides roughened sufficiently to prevent slip in the grips, employing any suitable means that does not significantly reduce the tensile strength across the section. This requirement is especially critical for thin specimens.

23.6 If a load-displacement recorder for autographic plotting of load-displacement curves is not available and a load-displacement curve for the test specimen is desired, the specimen shall be gage marked with a center punch, scribe marks, multiple device, or drawn with ink. Punch marks, if used, shall be light, sharp and accurately spaced. The gage marks shall be made on the same side of the specimen, in line with the two fasteners, and at a distance of 0.5 in. away from the ends of the overlapped portion of the specimen, for a gage length of (2e + s + 1) in.

The purpose of these two gage marks is to determine the relative movement of the two component straps across the joint.

23.7 If the test specimen is not gage marked in accordance with paragraph 23.6, it shall be marked in a fashion that will permit the accurate determination of the total relative movement of the two component straps at the ultimate load. Such a marking may be a single scribe mark across both components of the joint. Markings used shall in no way affect either the strength of the material or the strength of the joint.

24. TESTING APPARATUS AND EQUIPMENT

24.1 Loading System. The loading system to be employed in this test is a tension testing machine. This machine shall be maintained in good operating condition, used only in the proper loading range, and calibrated periodically in accordance with the latest revision of ASTM Methods E4, Verification of Testing Machines.

24.2 It is desirable to use a load-displacement recorder, such as an extensometer, for autographic plotting of load-displacement curves. Such a recorder, if used, should have a displacement range of approximately 0.50 in. over a gage length of (2e + s + 1) in., although use over a smaller gage length is permitted.

25. TEST PROCEDURE

25.1 Loading. The test specimen, prepared in accordance with the provisions of Section 23, shall be placed in the gripping or holding devices of the testing machine. It is essential that the load be transmitted axially to hold bending to a minimum. This implies that the centers of the grips shall be in alignment, insofar as practicable, with the axis of the specimen at the beginning and during the test. The specimen shall be gripped over approximately the final 4 in. of length at each end, although this length may be increased if necessary to avoid slippage in the grips. Shims of appropriate thicknesses shall be used as shown in Figure 14 if either t_1 or t_2 is greater than 0.10 in. to reduce loading eccentricity.

25.2 Speed of Testing. The speed of testing shall not be greater than that at which load and relative displacement readings can be made accurately. In addition, the speed of testing shall not exceed either a 0.05 in. per min. rate of separation of the two heads of the testing machine under load or a 100 lb. per min. rate of loading, whichever produces the greater rate of separation of the two heads of the testing machine under load.

25.3 Measurement of Relative Displacement. The load-displacement recorder, if employed, should be set at a gage length of $(2e + s + 1)$ in., with the ends of the measuring device 0.5 in. away from the edge of each overlap. Should this gage length be unattainable for the particular device used, the gage length for which the device was designed may be used provided that it is centered with reference to the two fasteners, i.e. each gage mark is at an equal distance from the fastener nearest to it.

25.3.1 If no load-displacement recorder is available and a load-deformation curve for the specimen is desired, displacement measurements between the gage marks made in accordance with paragraph 23.6 shall be made at appropriate intervals using a set of dividers or similarly suitable instrument. Accuracy should be on the order of 0.01 ± 0.005 in.

25.4 Measurement of Relative Displacement at Ultimate Load. Upon attainment of the ultimate load, or as soon thereafter as practicable, the testing machine drive shall be stopped and the specimen held in the strained position. Measurement of the total relative displacement at ultimate load shall be made between the marks made in accordance with paragraph 23.6 or 23.7 employing a device suitable for such a purpose. Accuracy should be on the order of 0.01 ± 0.005 in. After the completion of this measurement the specimen may be further strained to obtain the complete load-deformation curve or unloaded, as desired.

26. EVALUATION OF TEST RESULTS

26.1 The ultimate strength of the connection in single-shear, per fastener, shall be taken as one-half the value of the ultimate load attained in this test.

26.2 The load-deformation curve of the connection in single-shear, per fastener, shall be the load-deformation curve obtained from this test with the load values reduced by one-half. If no load-deformation curve was obtained from the test, and it is felt that deformations might govern in the design, the load-deformation curve shall be taken as a straight line from the origin to the point defined by one-half the ultimate load attained in this test and the relative displacement at ultimate load as measured per paragraph 25.4.

SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST

27. DEFINITION AND DESCRIPTION

27.1 The Single-Shear (Simulated Diaphragm Action) Test is a test designed to determine the single-shear capacity of a connection in a cold-formed steel diaphragm. The two joint components, each of the desired thickness and connected with two fasteners located parallel to the direction of force, are each clamped between two flat, heavy plates using high strength bolts. The flat plates are constrained by guide tracks to movement only in their own plane and in the direction of force. The force is transmitted from the flat plates to the joint components, and across the components by the fasteners. A sketch of the test fixture is presented as Figure 15.

28. TEST LIMITATIONS

28.1 This test, although considerably more complicated than the Single-Shear (Lap Joint) Test, is believed to be a good simulation of the behavior of a connection in a shear diaphragm. It readily lends itself to several specimen shapes and with no modifications can be used to simulate a double-shear connection. The primary limitations of this test are its complexity and the requirement for great care in machining and preparation of test specimens.

29. TEST SPECIMEN PARAMETERS

29.1 Figure 16 shows the typical test specimen configuration to be employed in the Single-Shear (Simulated Diaphragm Action) Test. All constant parameters are given in the figure. The nature of this test and the required tolerances demand that these parameters be closely met. The following values are to be used for the variable parameters:

29.1.1 Fastener spacing s. The fastener spacing s shall be taken as the greater of 2 in. or 8d, where d is the fastener diameter.

29.1.2 Specimen thicknesses t_1 and t_2. The specimen thicknesses t_1 and t_2 shall be identical to, and in the same position relative to the head of the fastener as, the actual application.

29.2 In addition to the test specimen two spacer plates, one of thickness t_1 and the other of thickness t_2, where t_1 and t_2 are the specimen thicknesses, are required. The typical spacer plate configuration is shown in Figure 17.

29.3 If either one or both components of the test specimen are not flat-shaped appropriate measures, including bending and cutting, may be taken to produce a configuration suitable for the test fixture, provided that such measures in no way affect the strength of the connection nor significantly alter the geometry of the section in the vicinity of the fasteners.

29.4 The material employed in this test shall be identical to that used in the actual application. Surface treatment, if any, shall remain undisturbed.

30. PREPARATION OF TEST SPECIMEN

30.1 Specimen components for the test may be removed from the parent stock by any suitable means, including mechanical cutting and shearing, that produces a clean, straight cut and does not measurably affect the material properties at a distance of 1/16 in. from the edge on the side nearest the fastener location. Spacer plates may be removed from the parent stock by any suitable means, provided that the final dimensions are met. Edge roughness incurred in this process that might prevent the component sections and spacer plates from mating completely shall be removed by a suitable means, preferably filing.

30.2 The four 9/16 in. holes shall be formed in the specimen components and spacer plates by either drilling or cutting with a hole saw. If desired, component parts may be stacked, clamped and drilled altogether. Rough edges incurred in this process shall be removed by a suitable means to leave a smooth, flat surface.

30.3 If the actual application is to involve the forming of holes in both component parts of the connection simultaneously, the two components of the test specimen shall be well aligned and suitably clamped in the final specimen configuration. Care shall be exercised to assure proper alignment. The fastener holes shall be formed with the specimen in this clamped position, employing the same hole diameters and forming techniques as used in the actual application.

30.4 If the actual application is to involve the forming of holes in each component of the connection individually, such holes shall be formed in each component of the test specimen employing the same hole diameters and forming techniques as used in the actual application. Additional care must be exercised to assure that both component parts of the test specimen will be well aligned when mated.

30.5 The two fasteners shall be installed from the same side of the test specimen with both component parts carefully mated and clamped together, employing a technique identical to that used in the actual application. In all circumstances the tightening torque shall be identical, or as nearly similar as practicable, to that employed in the actual application. If necessary or appropriate, suitably calibrated devices shall be used to assure fulfillment of this condition.

31. TESTING APPARATUS AND EQUIPMENT

31.1 Test Fixture. The basic test fixture consists primarily of a base plate with three tracked supports, a center support and two outside supports, as shown in Figure 18. The test specimen is bolted between two sets of shear plates and placed on the supports in the manner indicated in Figures 19 and 20. The shearing force, produced by a hydraulic ram, is transmitted to the shear plates and hence the test specimen through the arrangement depicted in Figure 21.

31.2 Test Fixture Components. The following are the descriptions of the various component parts of the test fixture. Mechanical connections are used rather than welding to eliminate the possibility of distortion due to heat.

31.2.1 Base Plate. A steel plate 10 in. wide, 16 in. long and 5/8 in. thick drilled with 3 rows of countersunk holes to accomodate 1/4 in. cap screws. A drawing of the base plate is presented as Figure 22.

31.2.2 Center Support. A steel tee section 12 in. long, 1 1/2 in. wide and 1 in. high drilled and tapped to be attached to the base plate with 1/4 in. cap screws. Teflon pads, 1/8 in. thick, are bonded to the inside surfaces to reduce friction. A drawing of the center support is presented as Figure 23.

31.2.3 Outside Supports. Two steel angles 15 in. long and 5/8 in. thick, with legs of 2 1/4 in. and 1 in., drilled and tapped to be attached to the base plate with 1/4 in. cap screws. A teflon pad 1/8 in. thick is bonded to the bottom inside surface to reduce friction. A drawing of an outside support is presented as Figure 24.

31.2.4 Vertical Guides. Two steel plates 1 1/4 in. wide, 15 in. long and 1/2 in. thick drilled to fit the outside supports and designed to restrain the test specimen from movement in the vertical plane. A drawing of a vertical guide is presented as Figure 25.

31.2.5 Shear Plates. Four steel plates (two to be positioned above and two below the test specimen) 2 7/8 in. wide, 18 in. long and 5/8 in. thick drilled with 9/16 in. diameter holes to accomodate the specimen between the two sets of plates. These plates are designed to transmit a shearing force in line with the fasteners across the two components of the test specimen. Drawings of a bottom and top shear plate are given as Figures 26 and 27, respectively.

31.2.6 Miscellaneous Items. In addition to such common items as dowels, cap screws, bolts and clamps, a number of miscellaneous items are required. These items include: a rigid support for the test fixture, such as an I-beam, with appropriate end restraints for the assembly; two yokes of a convenient size, complete with pins, to transmit the shearing force to the shear plates; a loading rod and restraining rod to transmit the shearing force to the yokes; a hydraulic ram to generate the force; a load measurement device, such as a load cell or calibrated rod; and two dial gages, with appropriate supports, accurate to 0.001 in. to measure the relative displacement of the two sets of shear plates.

32. ASSEMBLY OF TEST COMPONENTS

32.1 Placement of Test Specimen Between Shear Plates. The two bottom shear plates shall be placed on two supports approximately 11 in. apart, enabling access to the 9/16 in. holes from below, and separated by two 1 in. spacers as shown in Figure 28. The spacer plate of thickness t_1 shall be placed on one of the shear plates, taking care to assure that the 9/16 in. holes are in alignment and that the wider portion of the spacer plate is to the outside. The test specimen, prepared in accordance with Section 30, shall then be placed on the shear plates with the fastener heads directed downwards and the test specimen component of thickness t_2 on the shear plate containing the spacer plate. Care shall be taken to assure the proper alignment of the 9/16 in. diameter holes in the test specimen, spacer plate of thickness t_1 and shear plates. The top shear plate shall then be placed directly over that bottom shear plate which contains the spacer of thickness t_1 and test specimen component of thickness t_2. It is recommended that 17/32 in. dowels be used to aid in the alignment of the 9/16 in. holes. After proper alignment is attained, 1/4 in. dowels shall be placed through the dowel holes in the top and bottom shear plates and both plates shall be clamped to the supports. The spacer plate of thickness t_2 shall then be placed over the test specimen component of thickness t_1, again assuring the alignment of the 9/16 in. holes. The remaining top shear plate shall then be placed directly over the other bottom shear plate. After properly aligning the 9/16 in. holes, 1/4 in. dowels shall be placed through the dowel holes in the top and bottom shear plates and both plates shall be clamped to the supports.

32.2 Bolting of Test Specimen Between Shear Plates. The test specimen shall be bolted between the shear plates with eight 1/2 in. high strength bolts 2 1/2 in. long. With the shear plates clamped to the supports, as described in the previous paragraph, the bolts shall be placed through the 9/16 in. holes in the plates from below, with a washer under both the head of the bolt and the nut. After all eight bolts are installed and finger-tight, they shall all be torqued to 40 ft.-lbs. using an accurately calibrated torque wrench, and then torqued again to 80 ft.-lbs. This tightening produces a friction joint and avoids stress concentrations and distortions due to bearing of the bolts on thin steel sheeting. After the final tightening the clamps holding the plates to the supports and the 1/4 in. dowels shall be removed.

32.3 Assembly of Basic Test Fixture. The center support and two outside supports are attached to the base plate with 1/4 in. hexagon socket head cap screws. The screws are placed through the bottom of the base plate into the three supports in such a manner that the final configuration is as shown in Figure 18.

This assemblage is then clamped to a rigid support in such a manner that the longitudinal axis of the assemblage coincides with the longitudinal axis of the support.

32.3.1 The shear plates, with the test specimen bolted between them in accordance with paragraph 32.2, shall be lifted from the supports and placed into the assembly described in the preceding paragraph. Extreme care shall be exercised to assure that no bending or twisting of the specimen is incurred during this process. The test specimen shall be centered in the fixture by carefully sliding both sets by shear plates simultaneously into the desired position. With the specimen centered, 1/8 in. thick teflon pads shall be placed between the edges of the shear plates and the outside supports. The two vertical guides shall then be attached to the tops of the outside supports with 1/4 in. hexagon socket head cap screws. Teflon pads, 1/8 in. thick, shall be placed between the shear plates and vertical guides in such a manner that they are centered under the No. 5 cap screw holes, and No. 5 hexagon socket head cap screws shall be positioned and finger-tightened to assure a positive restraint in the vertical direction. Figures 19 and 20 show the configuration of the basic test fixture in plan view and vertical section, respectively.

32.4 Completion of Fixture Assembly. With the specimen installed in the basic test fixture and the test fixture clamped to a rigid support as prescribed in the two preceding paragraphs, the following steps will complete assembly of the test fixture. A yoke shall be connected to each set of shear plates with a 5/8 in. diameter pin. A restraining rod shall be attached to one of the yokes and supported at its opposite end in such a manner that it provides an immovable support and its axis coincides with the longitudinal axis of the test specimen. The restraining rod may be instrumented with strain gages or similar devices to measure the force transmitted across the test specimen with sufficient accuracy and it should be threaded at one or both ends to enable sufficient tightening to prevent substantial rigid body motion of the test specimen. A loading rod shall be attached to the other yoke and passed through a hydraulic ram with a hollow core, supported such that its axis coincides with the longitudinal axis of the test specimen. If the restraining rod is not instrumented, a load cell shall be placed between the hydraulic ram and the end support to measure the force generated. A drawing of the completely assembled test fixture is shown as Figure 21.

32.4.1 Two dial gages, accurate to 0.001 in. and supported in a suitable manner, shall be positioned as shown in Figure 29 to measure the relative displacement of the two sets of shear plates.

33. TEST PROCEDURE

33.1 Loading. The test specimen, prepared and installed in the test fixture in accordance with the provisions of Sections 30 and 32, shall be loaded by producing a tensile force in the loading rod by means of the hydraulic ram. There shall be a sufficient number of load increments to assure the production of a proper load-displacement curve, with a minimum of ten increments used. It is recommended that the magnitude of the load increment be reduced as the ultimate load is approached to improve the accuracy in determining the ultimate load.

33.2 Measurement of Relative Displacement. Both dial gages, positioned in accordance with paragraph 32.4.1, shall be read and the readings recorded at the beginning of the test (zero load) and at each load increment thereafter. The relative displacement of the two component parts of the test specimen shall be the difference in the displacements of the two sets of shear plates.

34. EVALUATION OF TEST RESULTS

34.1 The ultimate strength of the connection in single-shear, per fastener, shall be taken as one-half the value of the ultimate load attained in the test.

34.2 The load-deformation curve of the connection in single-shear shall be the load-deformation curve obtained from the test, with the values of the load taken as one-half those obtained from the test.

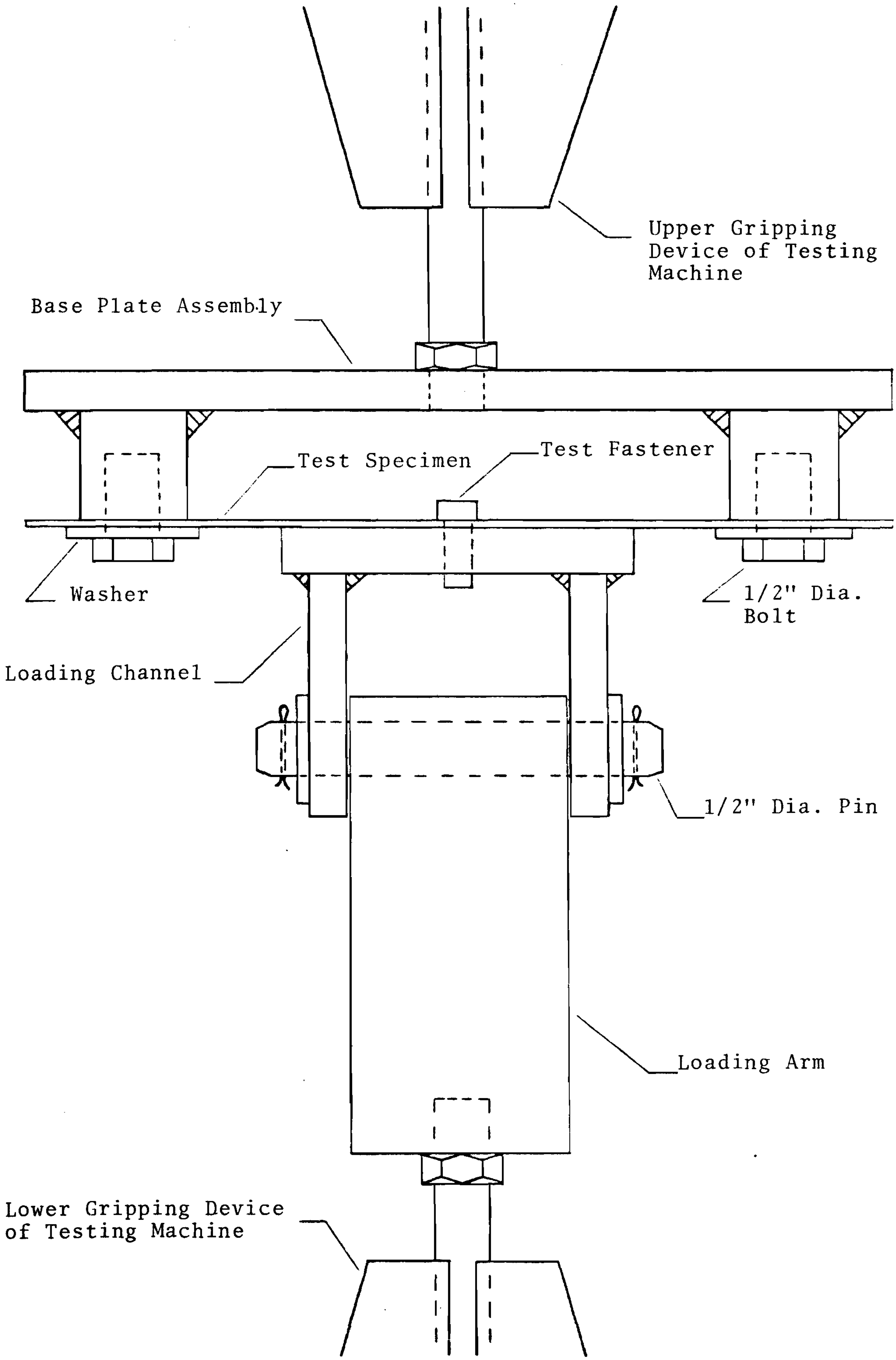


FIGURE 1. UPLIFT TEST FIXTURE FOR PULL-OVER TEST WITH SPECIMEN INSTALLED

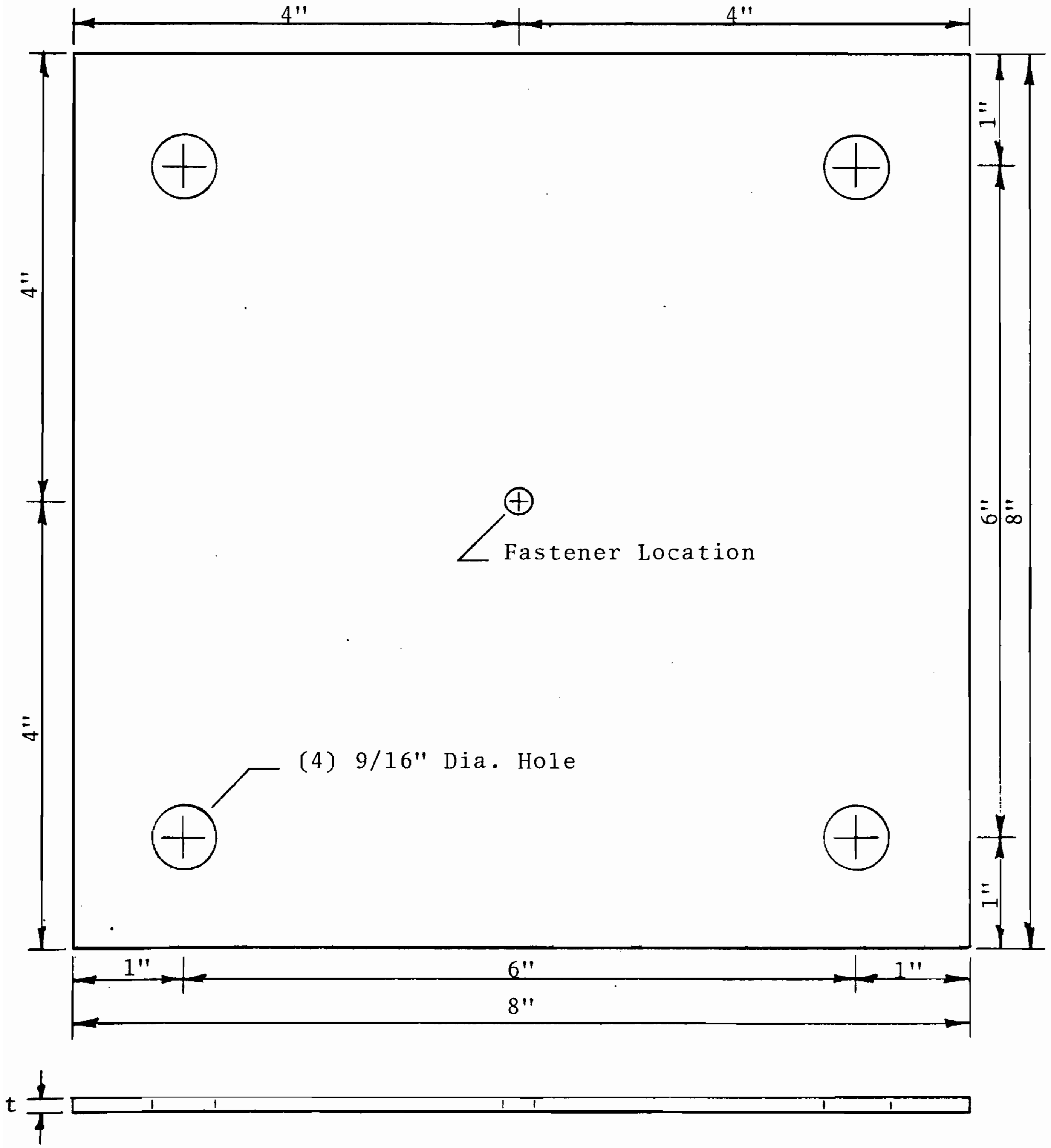


FIGURE 2. TEST SPECIMEN PARAMETERS FOR FLAT SECTIONS TESTED IN UPLIFT

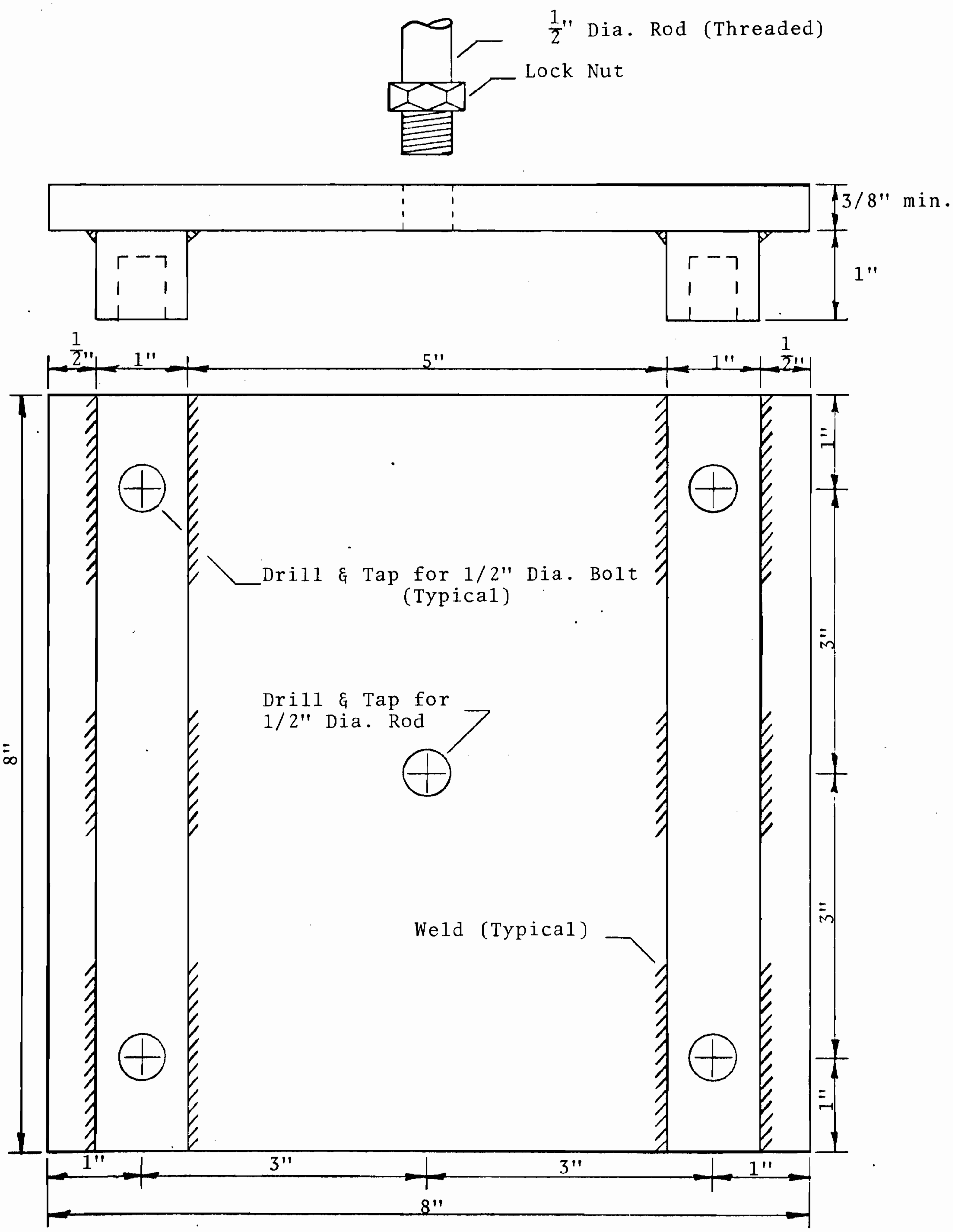


FIGURE 3. BASE PLATE ASSEMBLY FOR UPLIFT TESTS

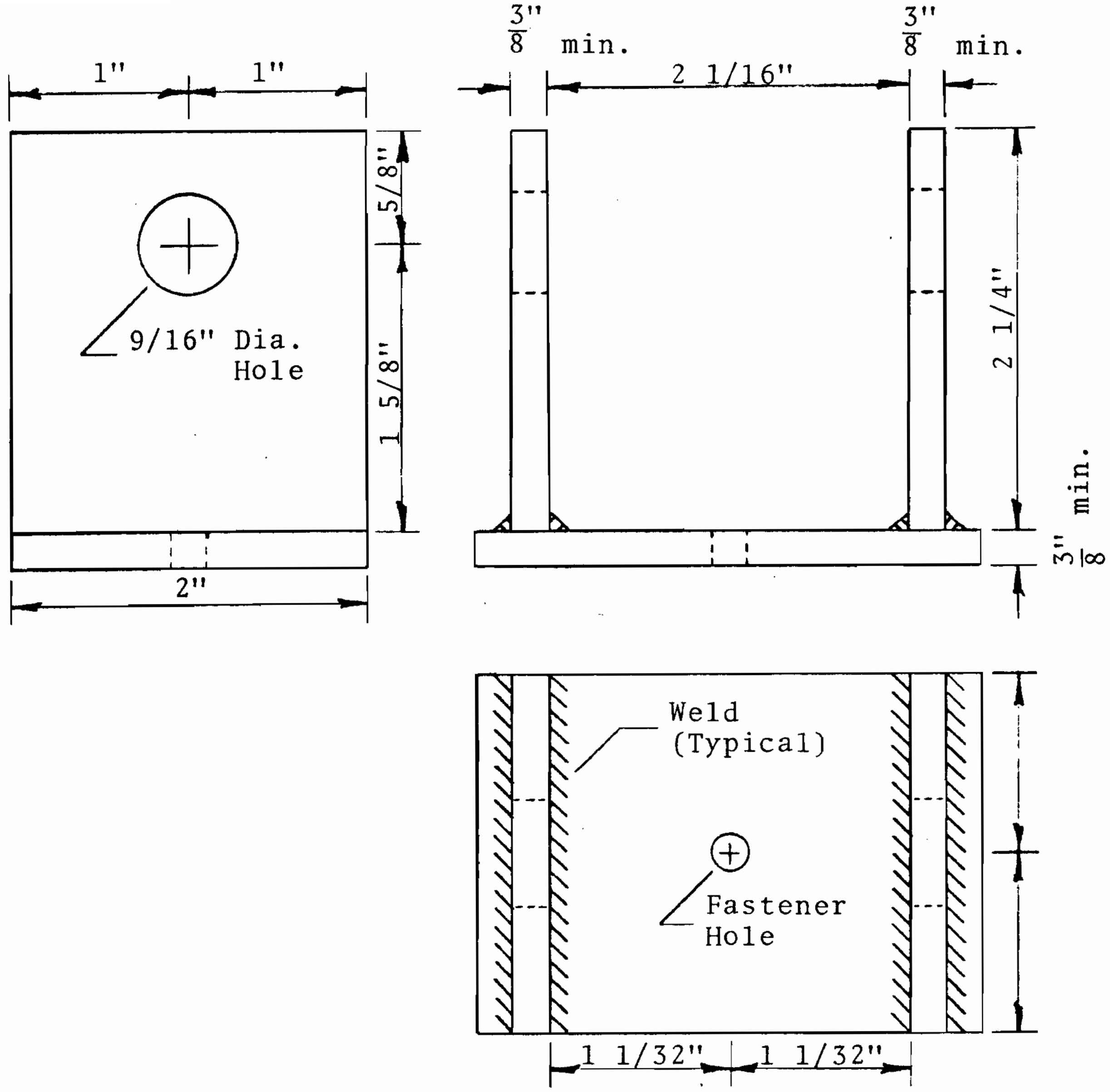


FIGURE 4. LOADING CHANNEL FOR UPLIFT TESTS

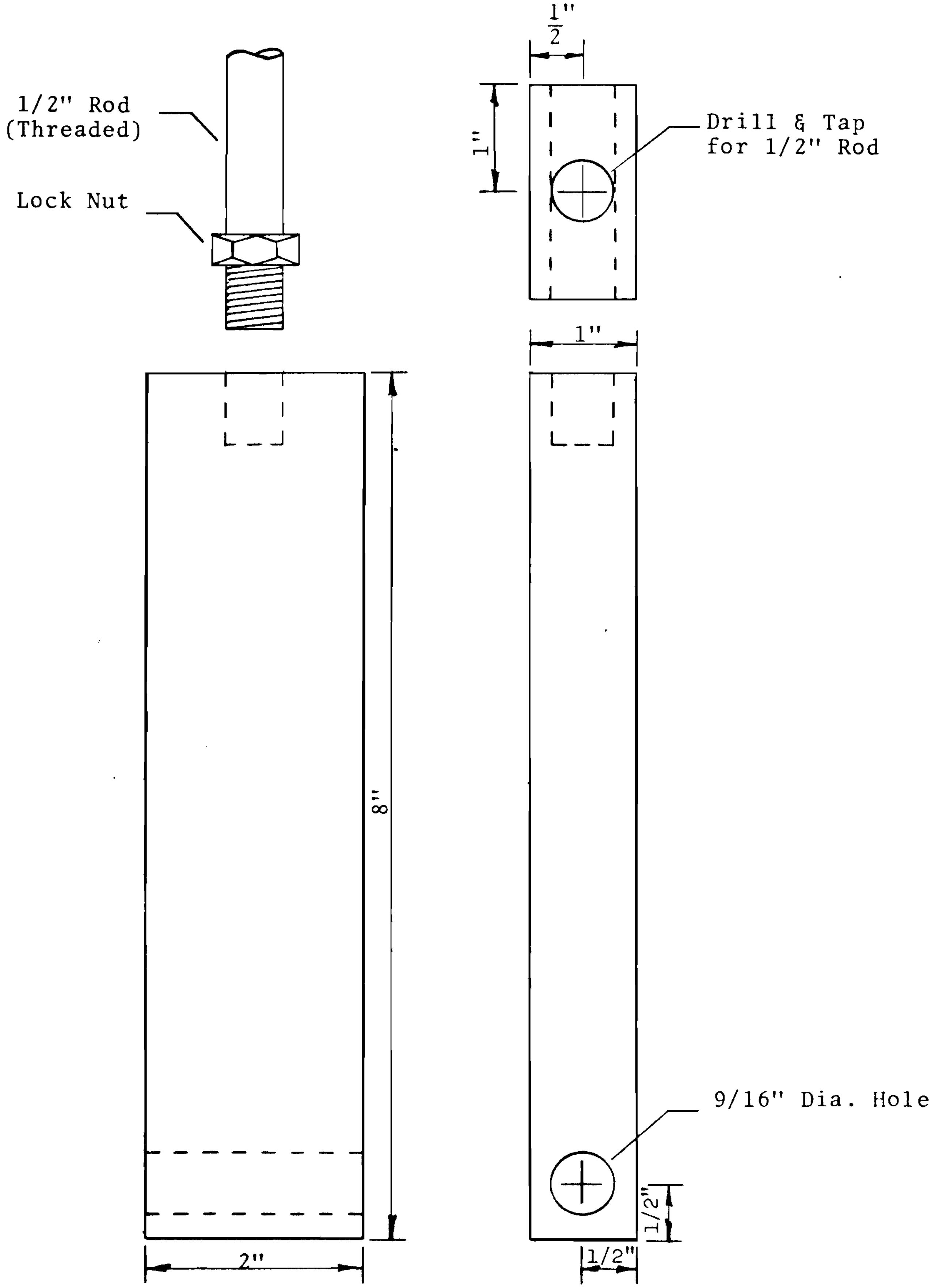
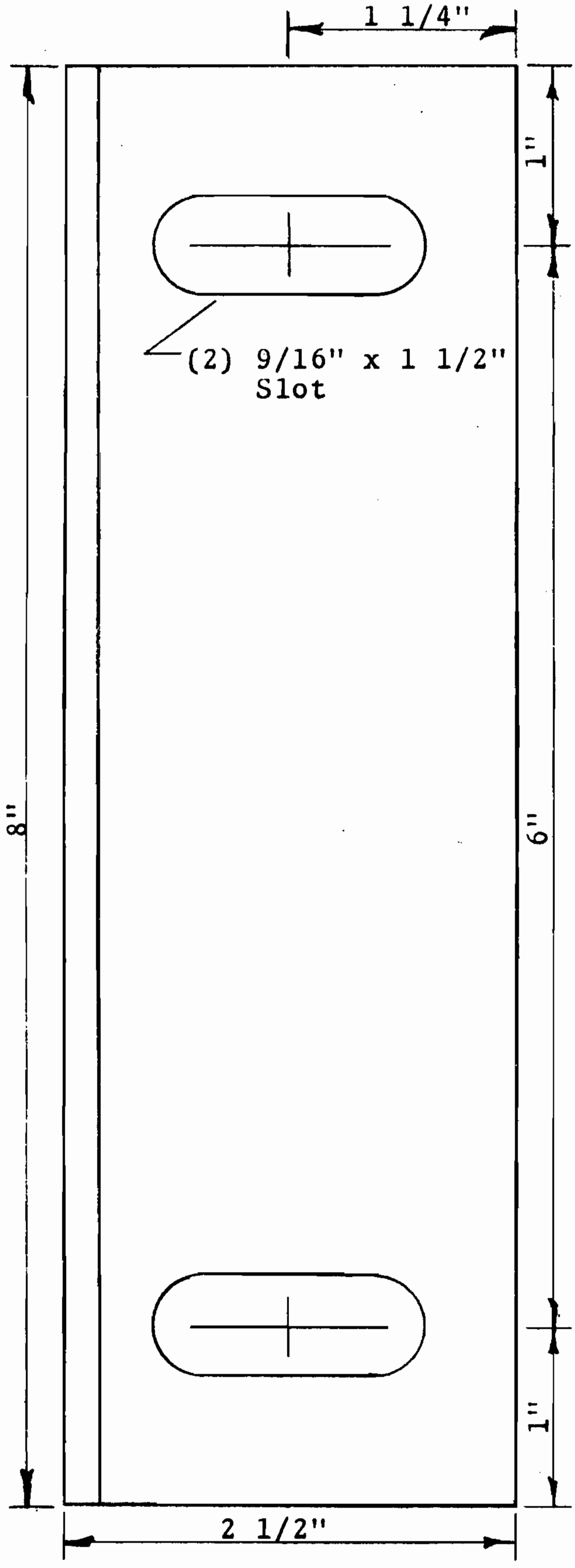


FIGURE 5. LOADING ARM FOR UPLIFT TESTS



L 2 1/2 x 1 1/2 x 3/16

FIGURE 6. SUITABLE ANGLE SECTION FOR UPLIFT TESTS

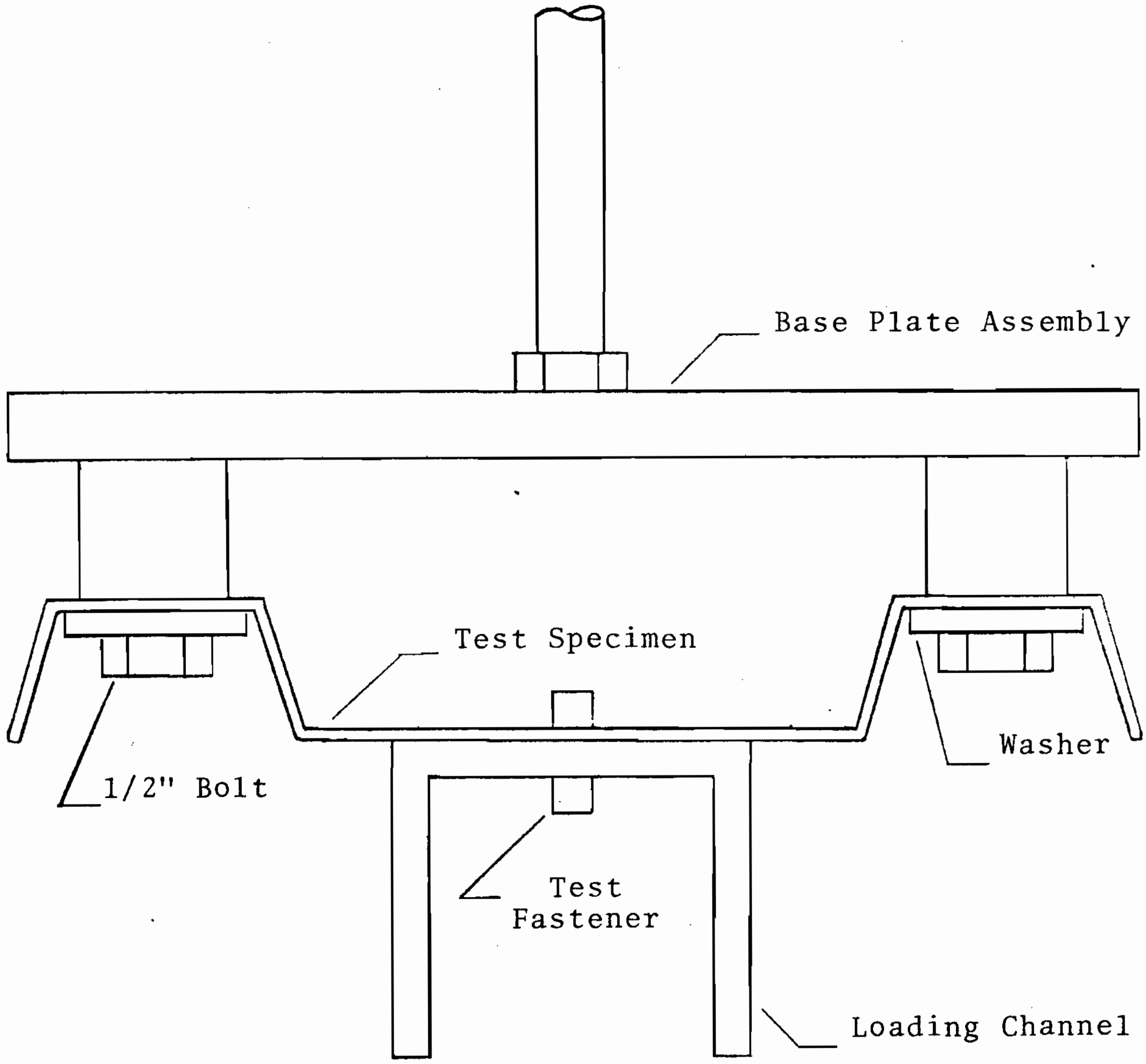


FIGURE 7. TEST SPECIMEN INSTALLATION FOR UPLIFT TESTS WITH 9/16 IN. HOLES IN THE SAME PLANE

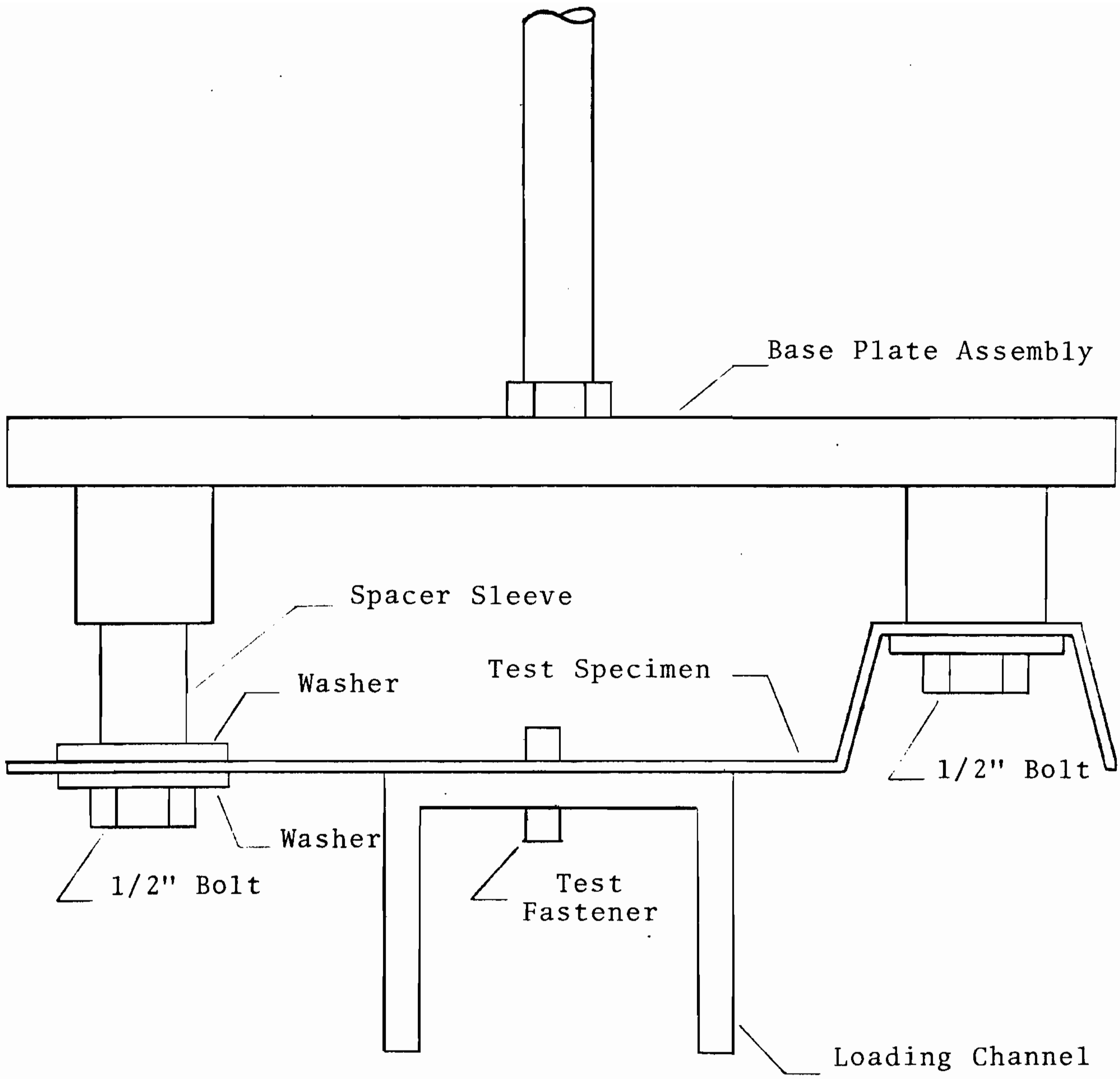


FIGURE 8. TEST SPECIMEN INSTALLATION FOR UPLIFT TESTS WITH 9/16 IN. HOLES IN DIFFERENT PLANES

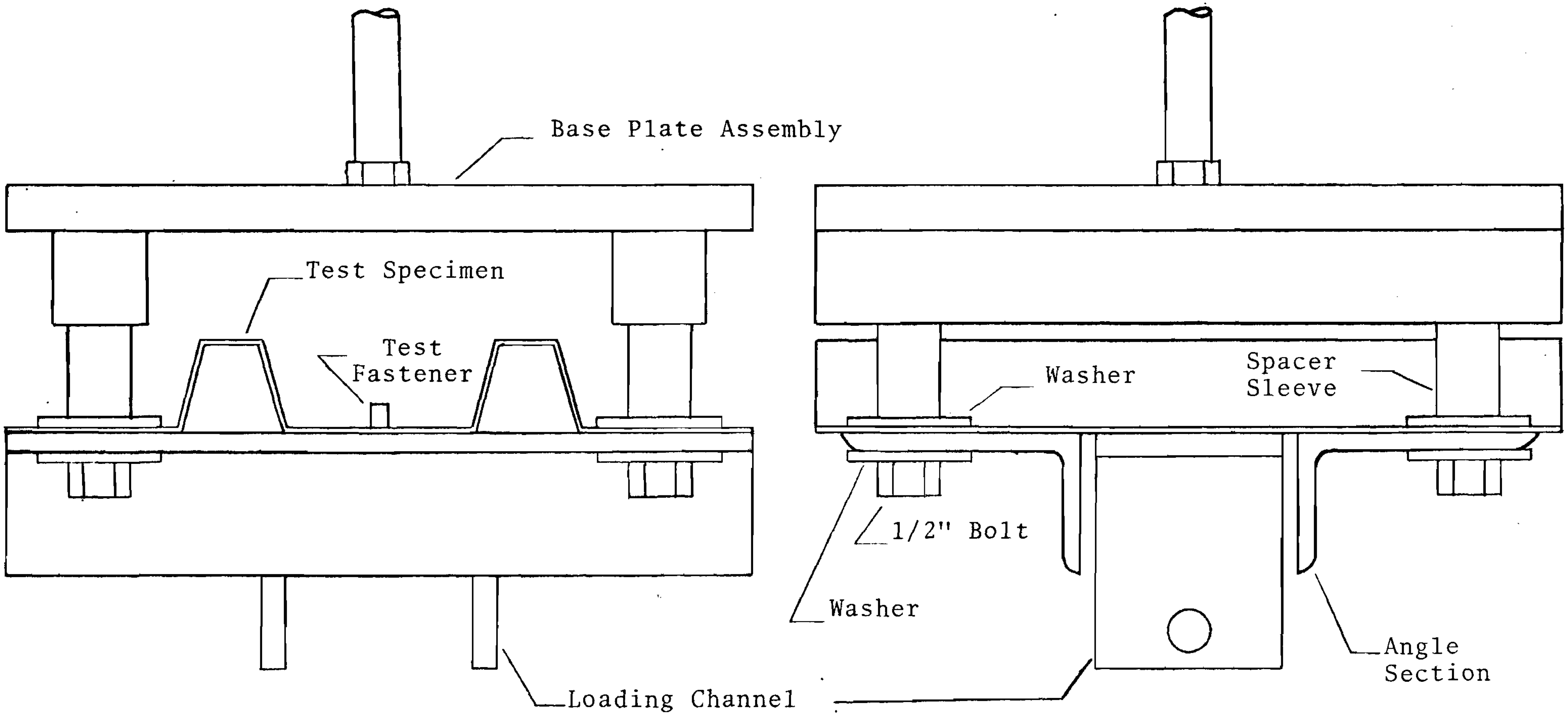


FIGURE 9. TEST SPECIMEN INSTALLATION FOR UPLIFT TESTS WITH FLEXIBLE CORRUGATED SPECIMENS

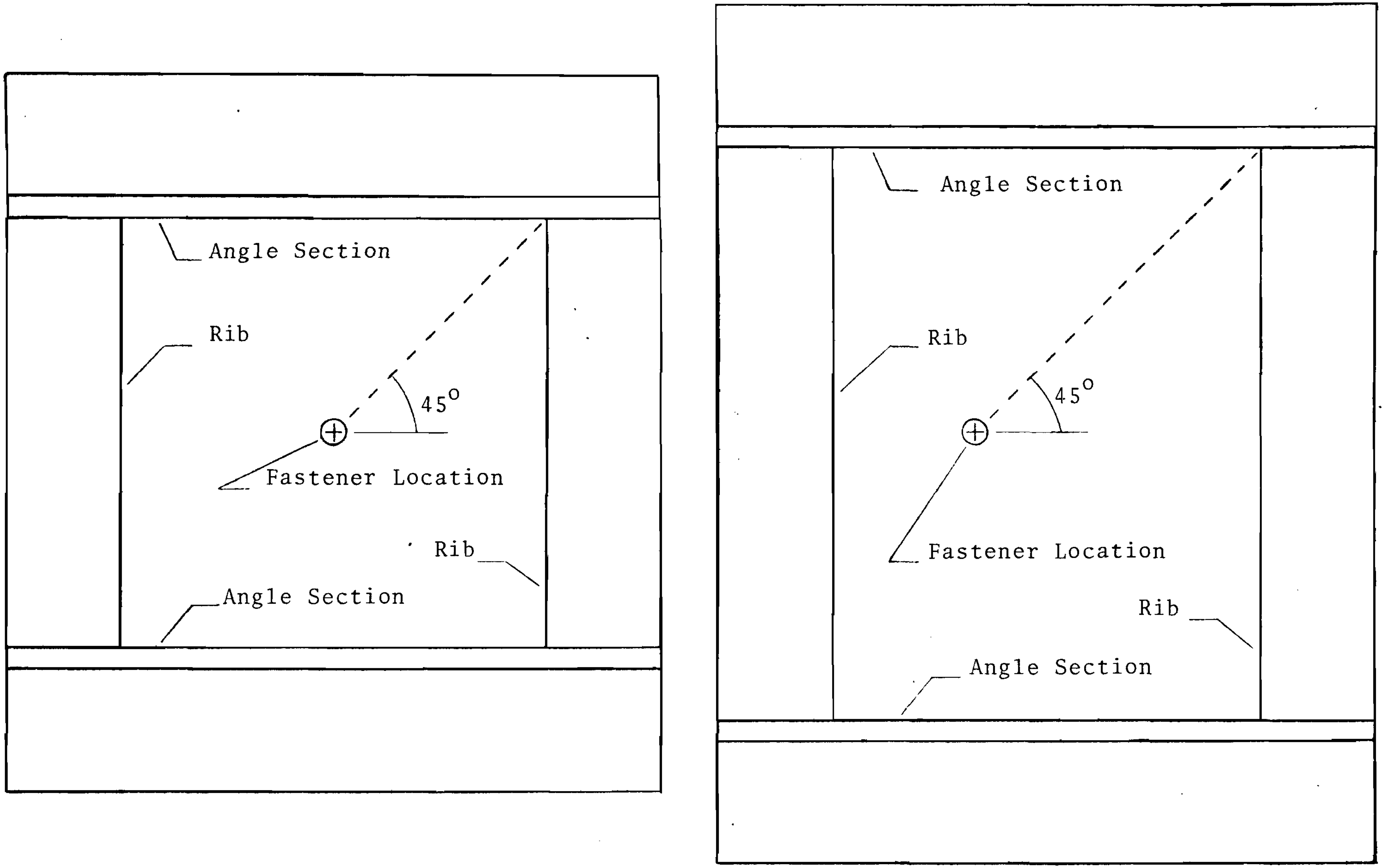


FIGURE 10. ANGLE SECTION LOCATION FOR PULL-OVER TESTS

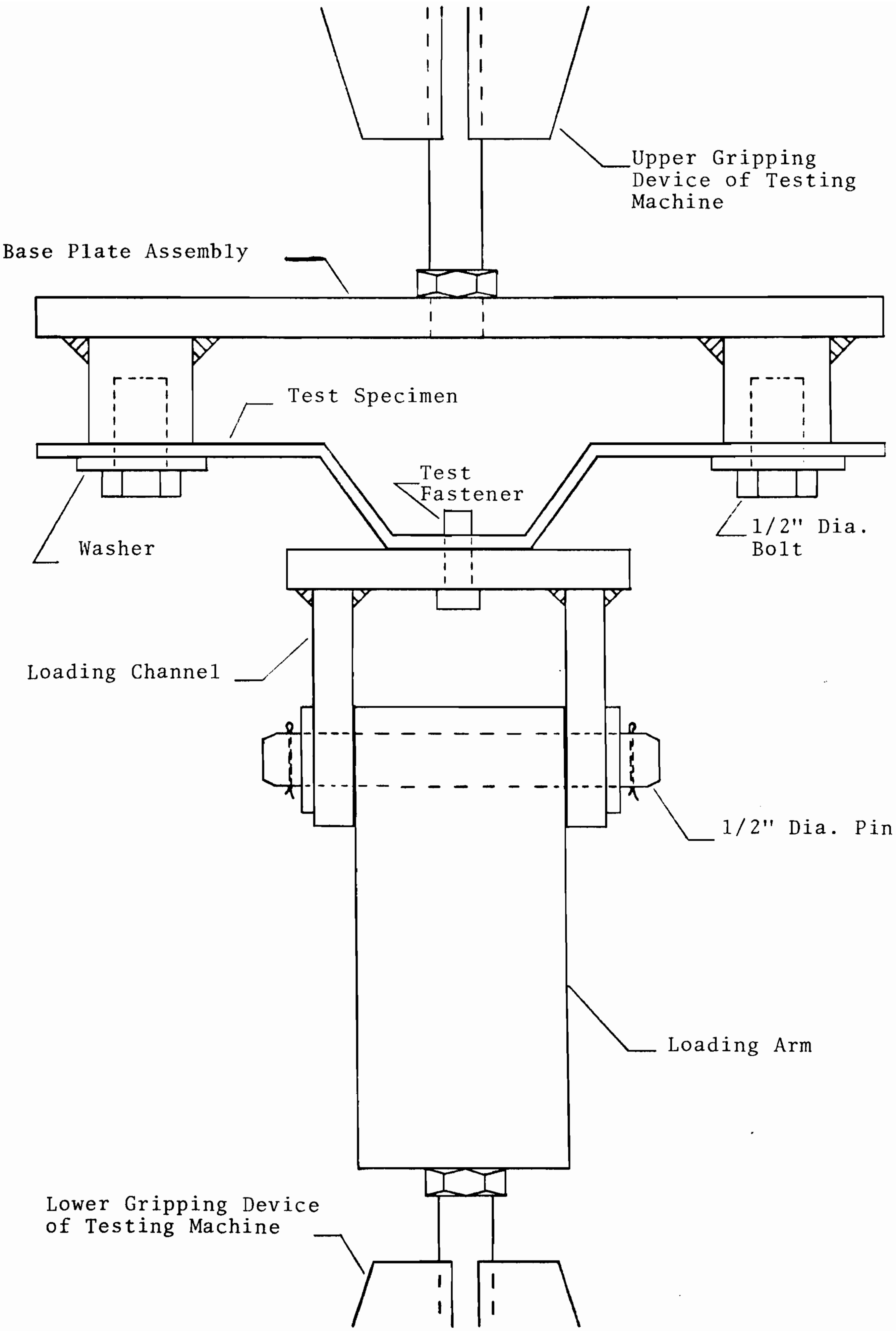


FIGURE 11. UPLIFT TEST FIXTURE FOR PULL-OUT TEST WITH SPECIMEN INSTALLED

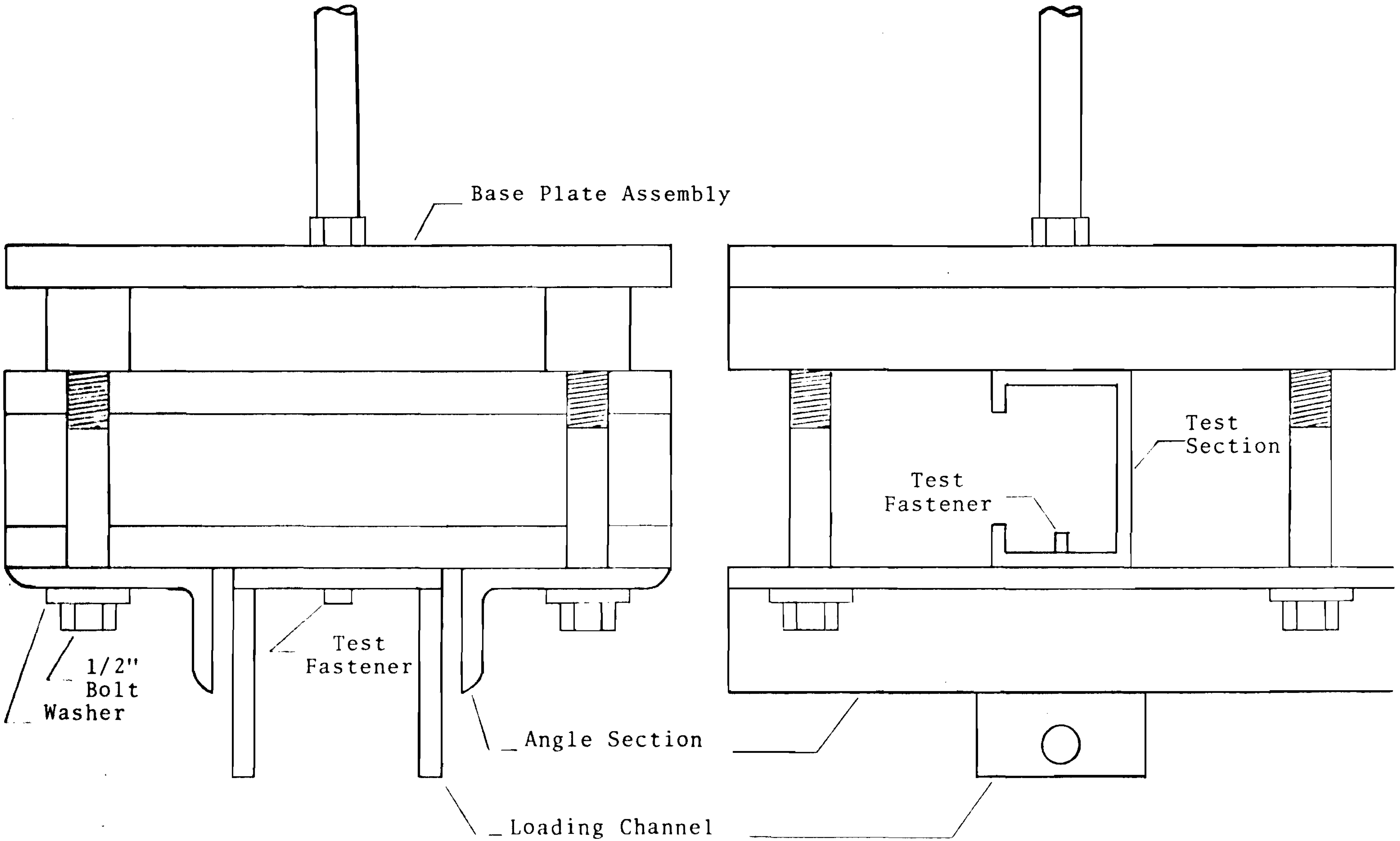


FIGURE 12. TEST SPECIMEN INSTALLATION FOR UPLIFT TESTS WITH FORMED SECTIONS

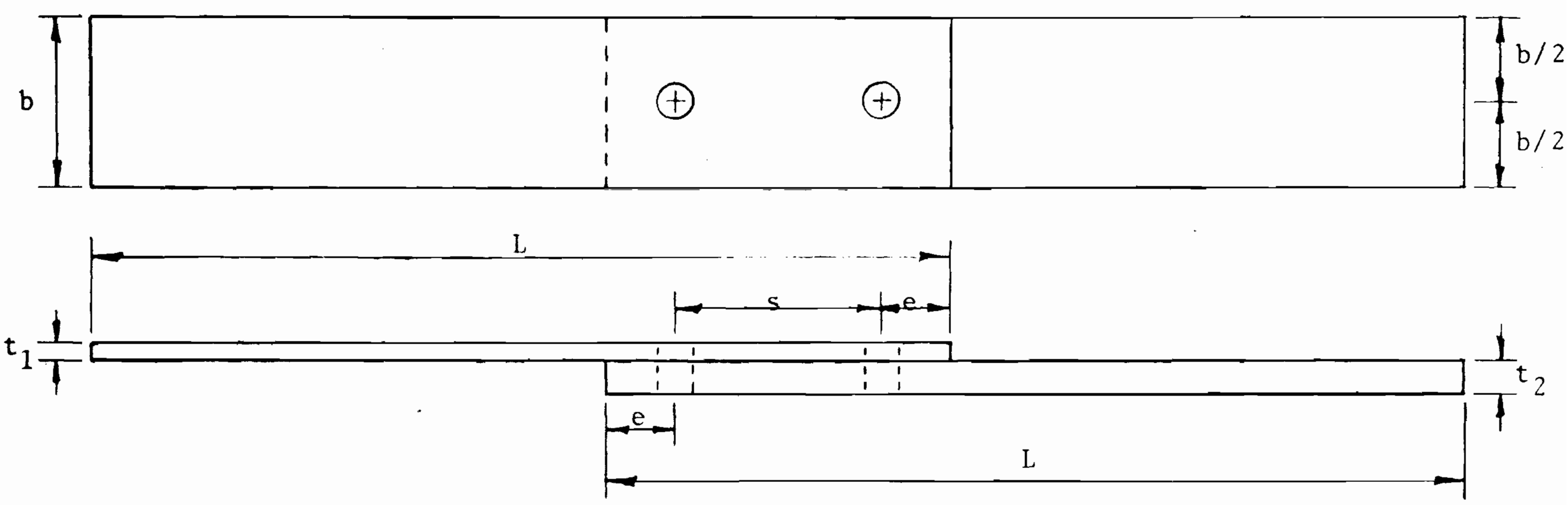


FIGURE 13. SINGLE-SHEAR (LAP JOINT) TEST SPECIMEN PARAMETERS

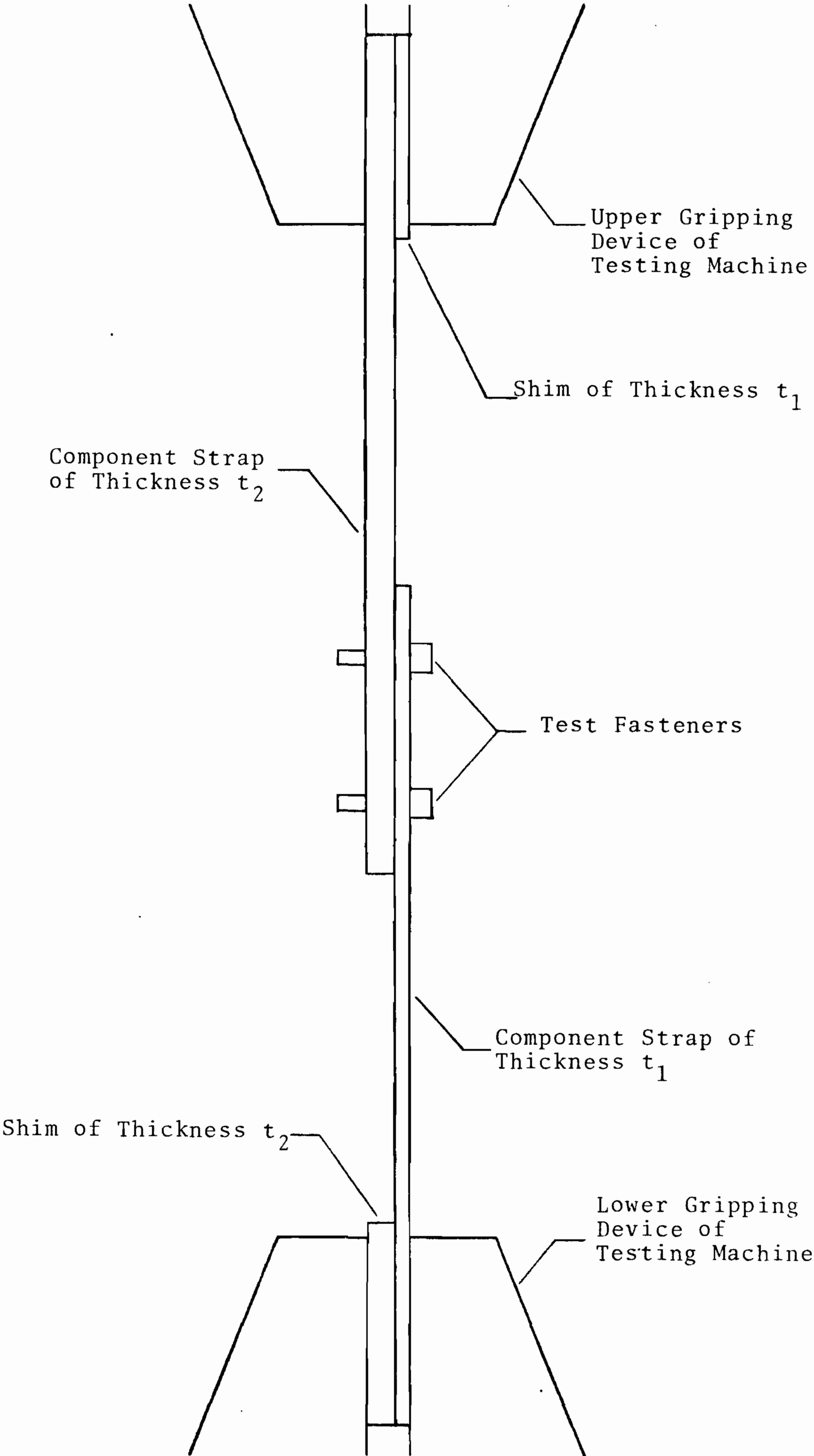


FIGURE 14. TEST SPECIMEN CONFIGURATION WITH SHIMS FOR SINGLE-SHEAR (LAP JOINT) TEST

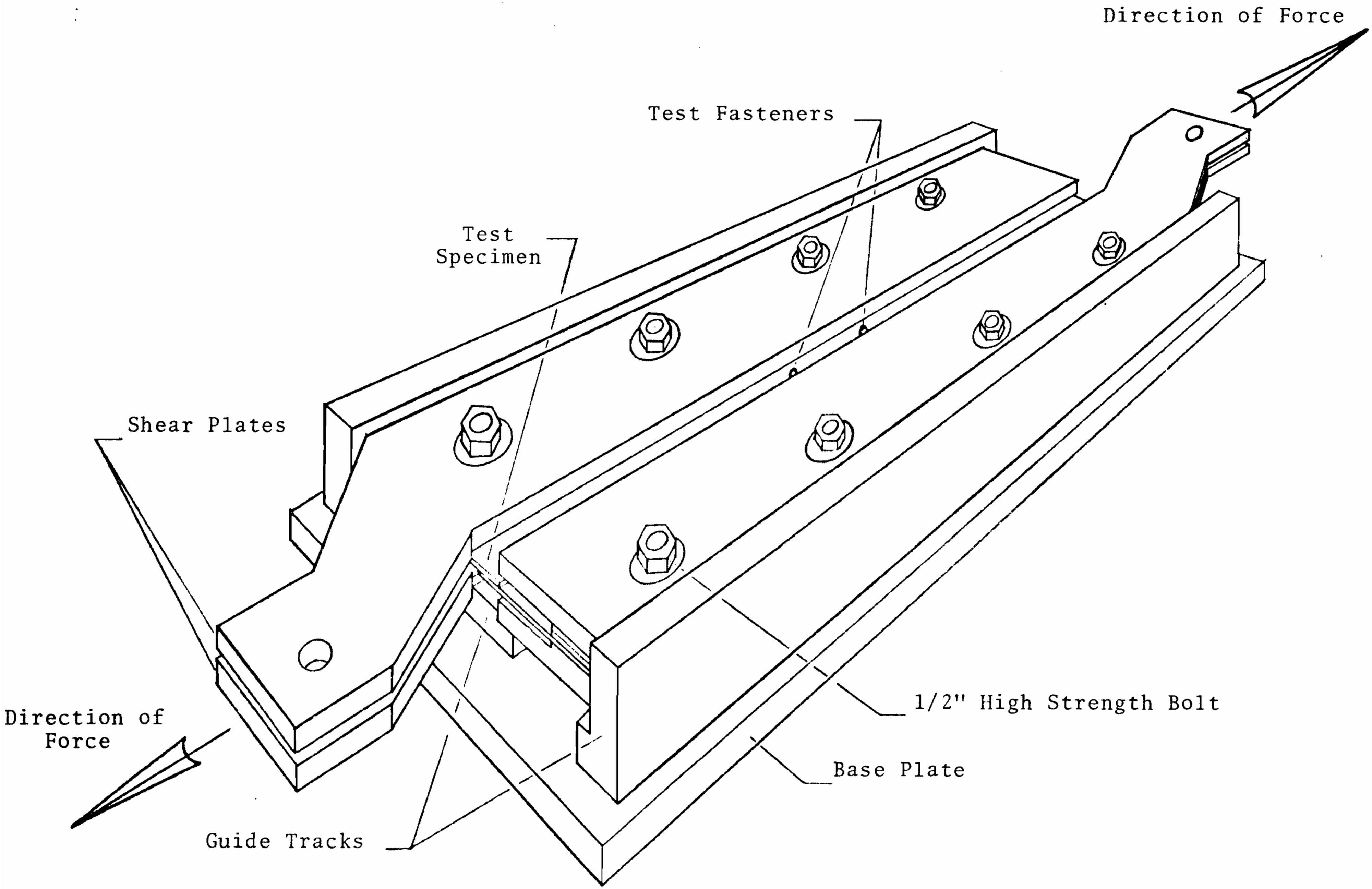


FIGURE 15. SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST FIXTURE WITH SPECIMEN INSTALLED

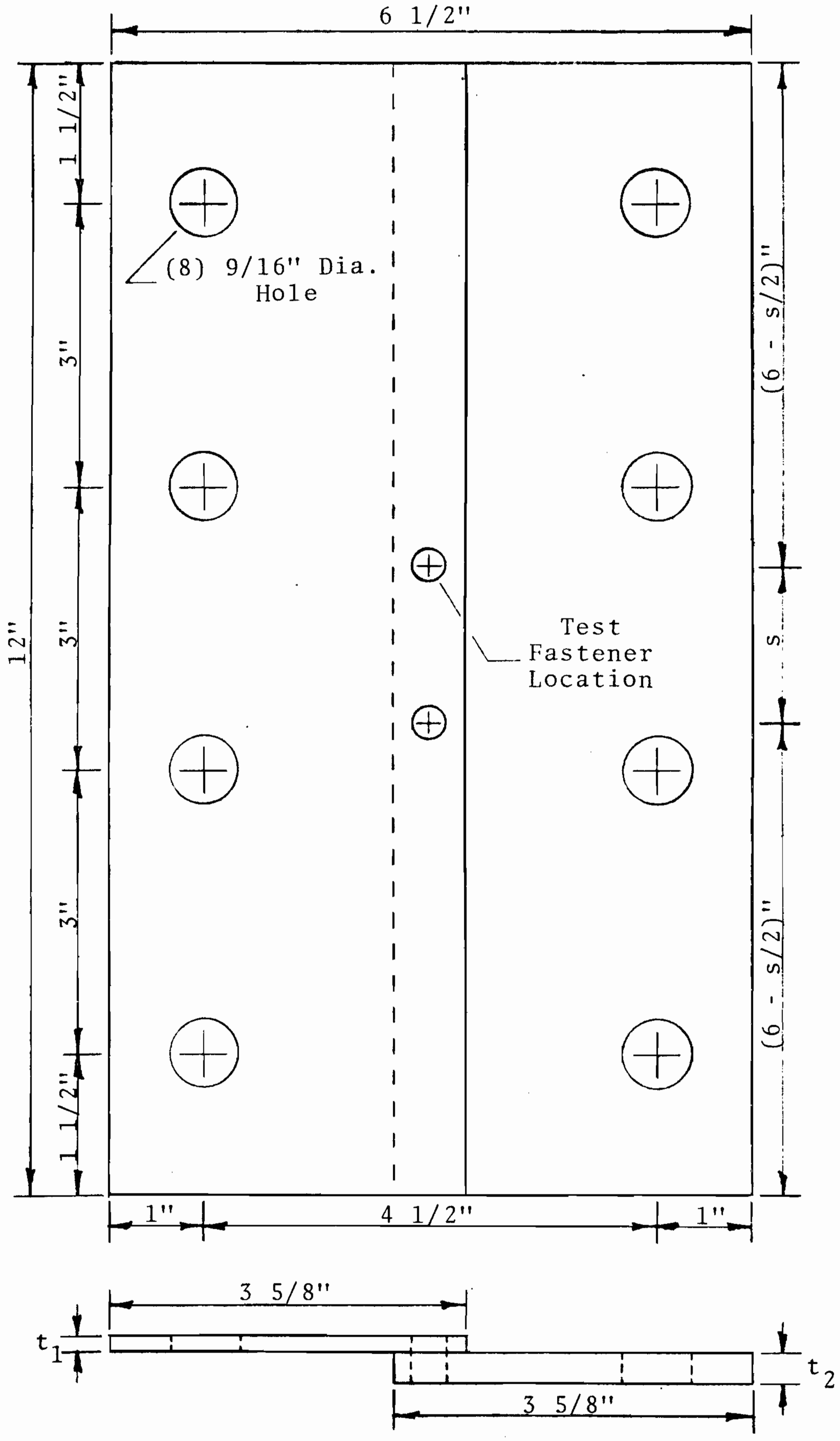


FIGURE 16. SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST SPECIMEN

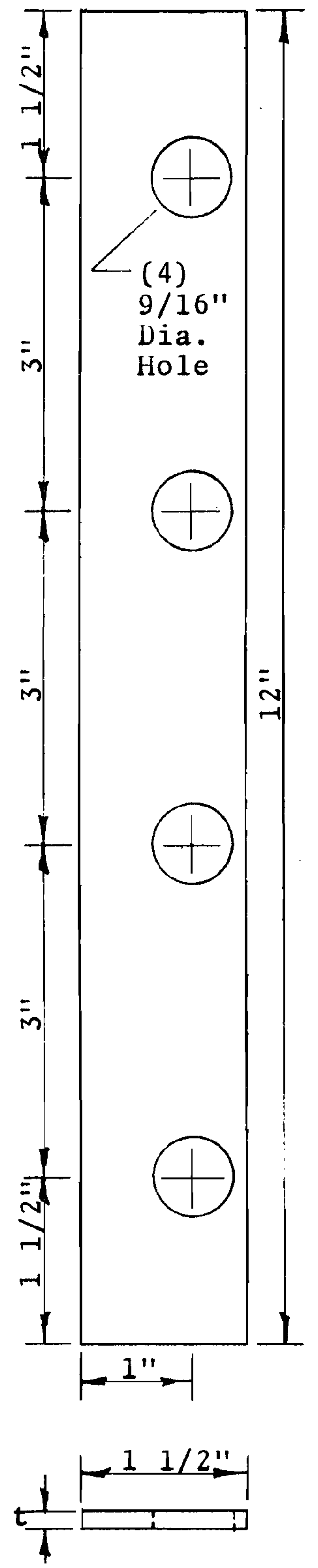


FIGURE 17. SPACER PLATE FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST SPECIMEN

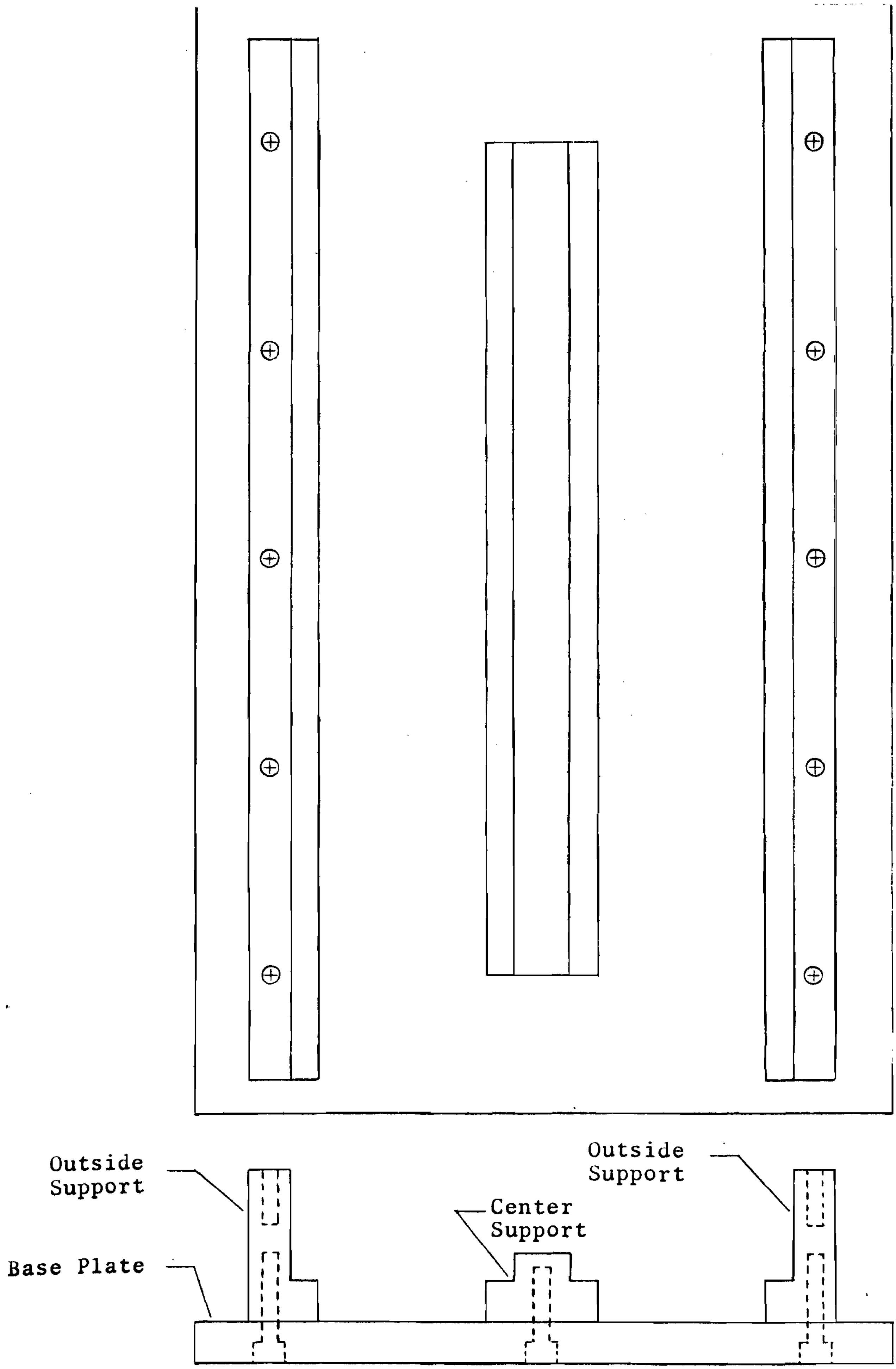


FIGURE 18. ASSEMBLY OF BASIC TEST FIXTURE COMPONENTS FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST FIXTURE

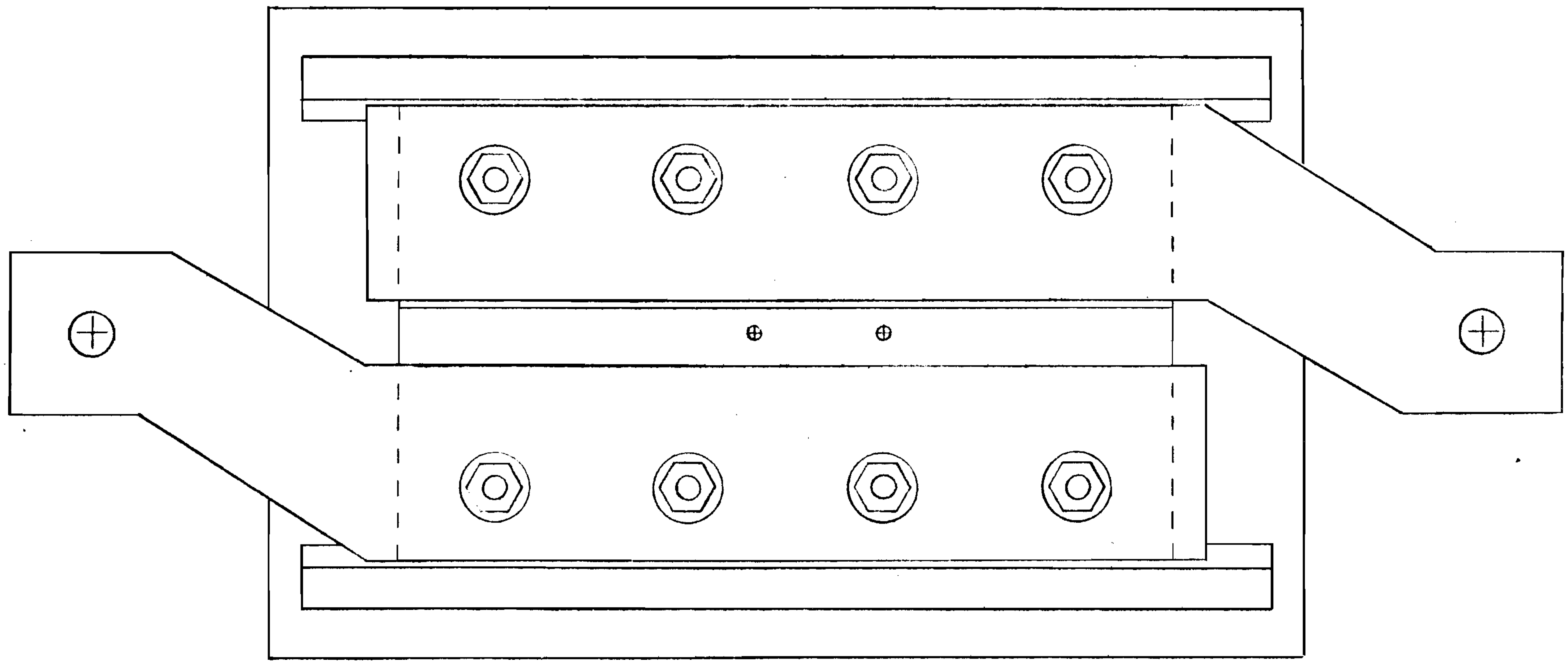


FIGURE 19. PLAN VIEW OF TEST FIXTURE CONFIGURATION FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST

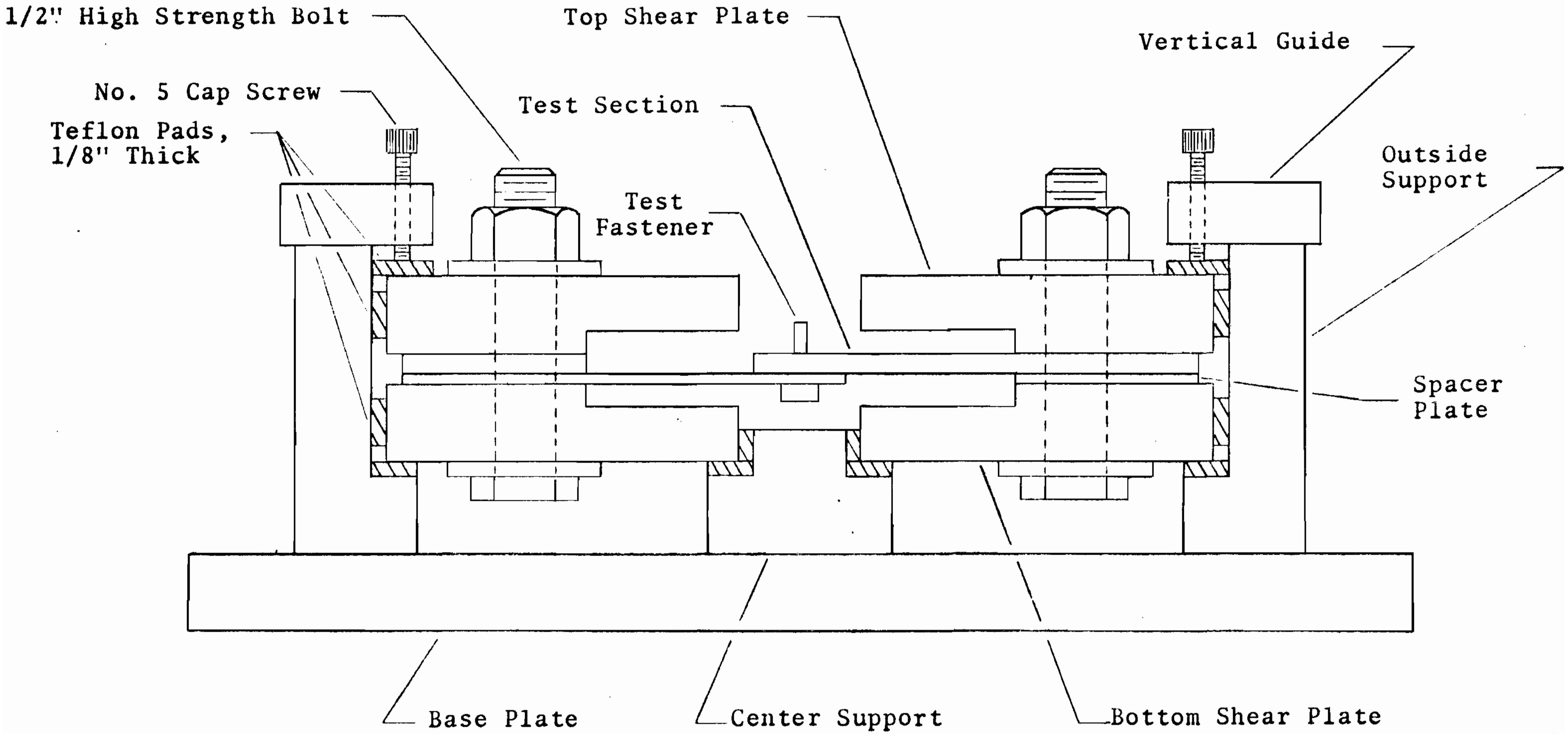


FIGURE 20. VERTICAL SECTION VIEW OF TEST FIXTURE CONFIGURATION FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST

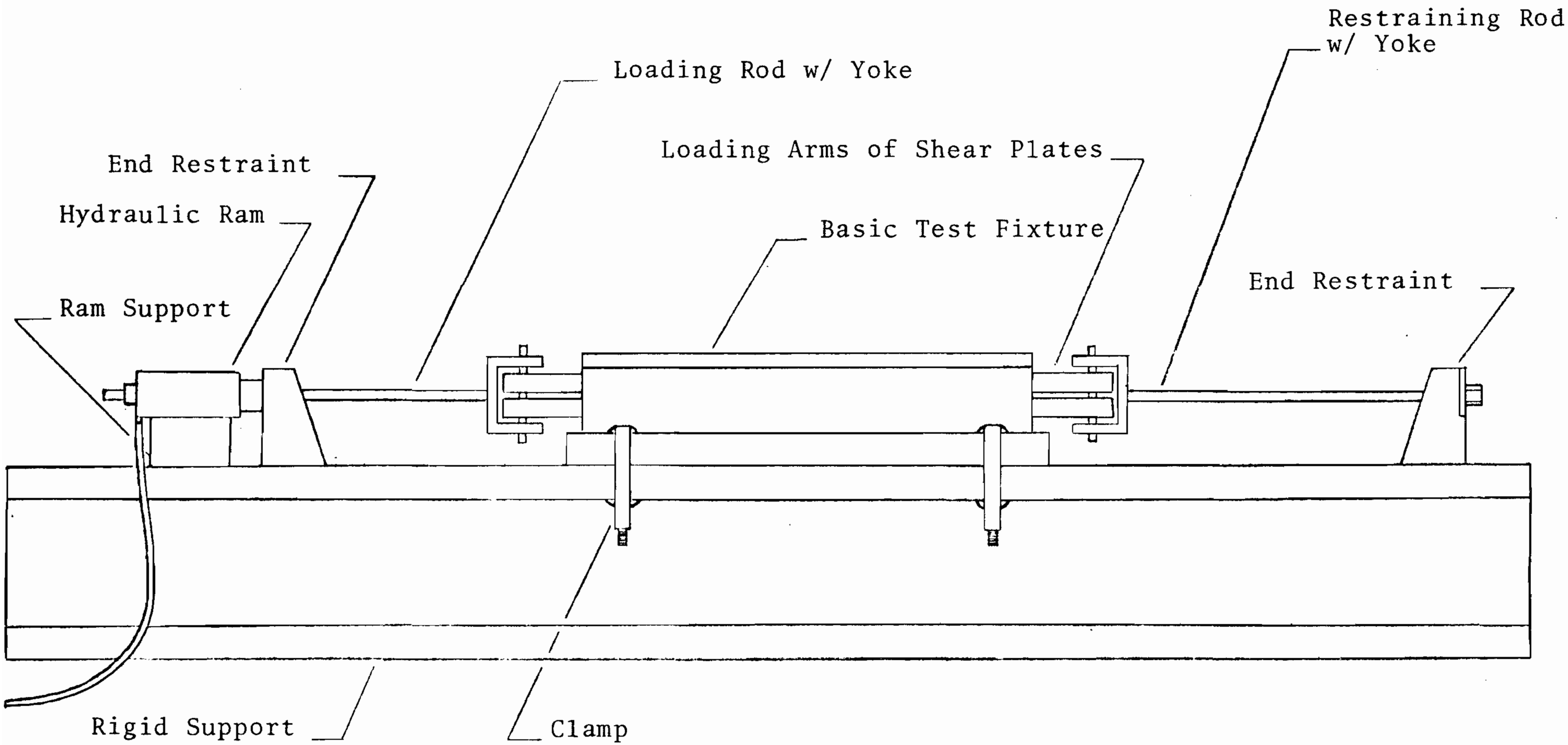


FIGURE 21. ELEVATION VIEW OF COMPLETELY ASSEMBLED TEST FIXTURE FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST

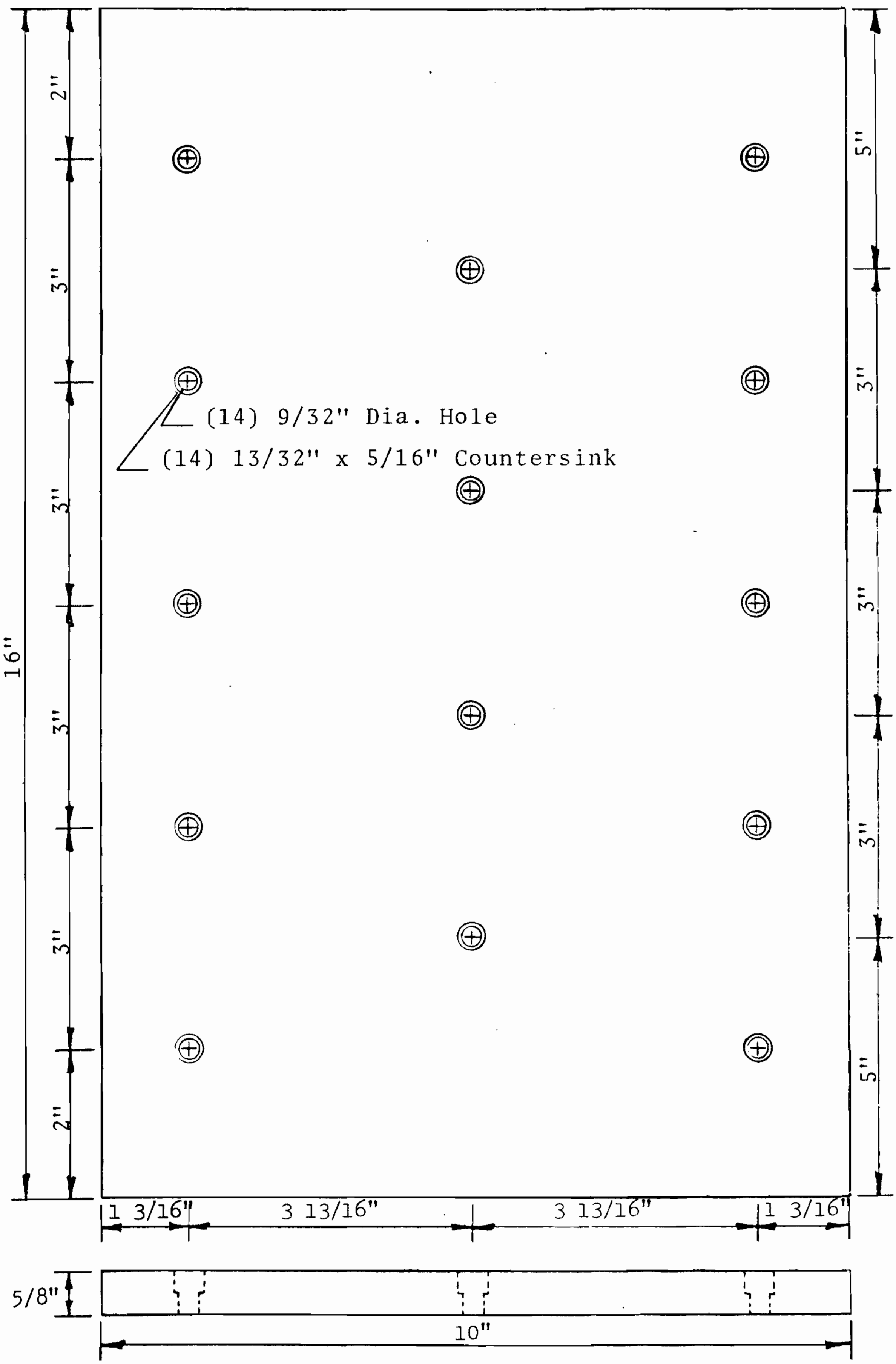


FIGURE 22. BASE PLATE FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST FIXTURE

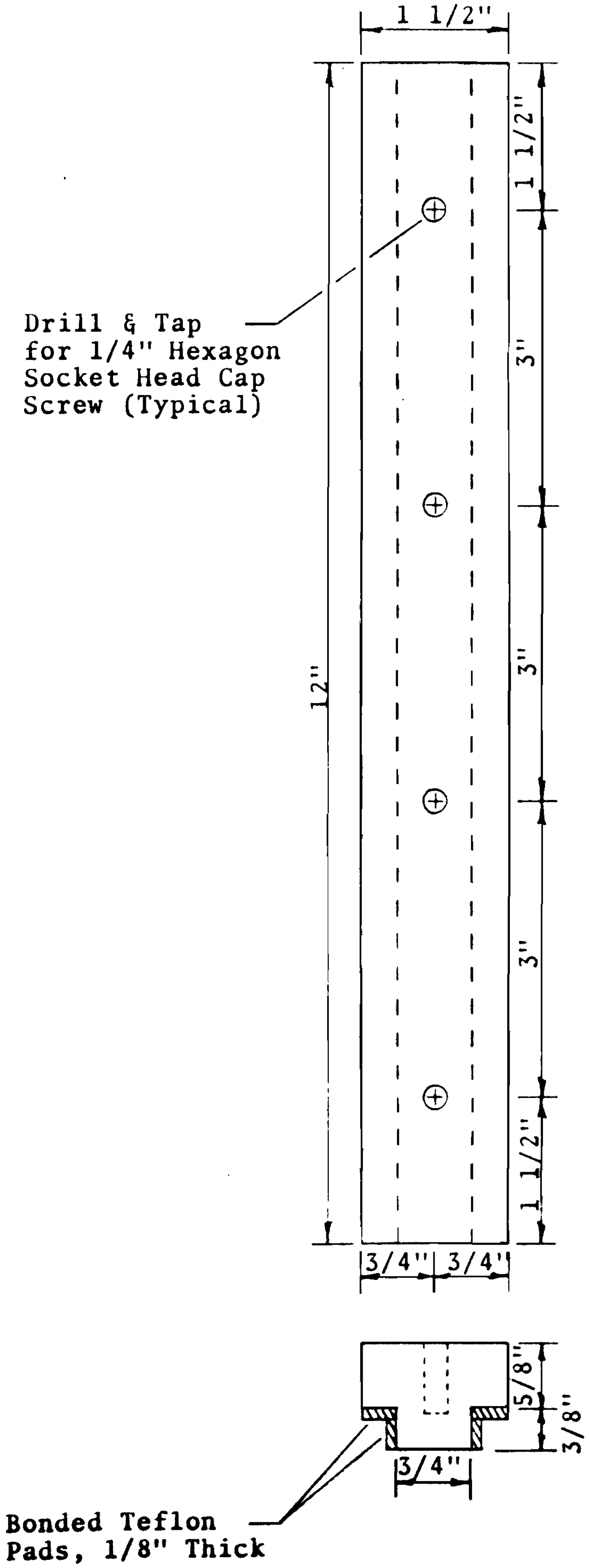


FIGURE 23. CENTER SUPPORT FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST FIXTURE

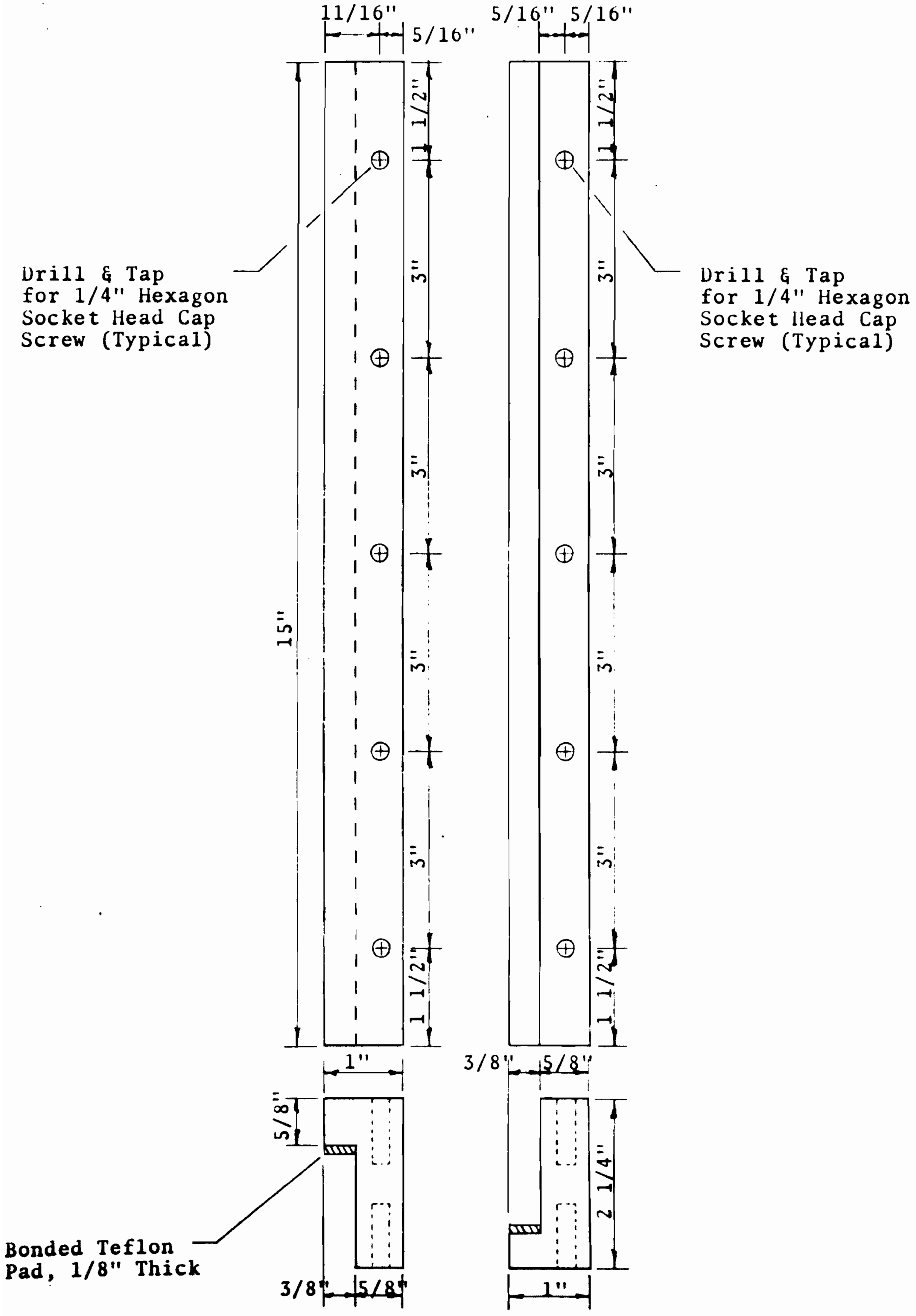


FIGURE 24. OUTSIDE SUPPORT FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST FIXTURE

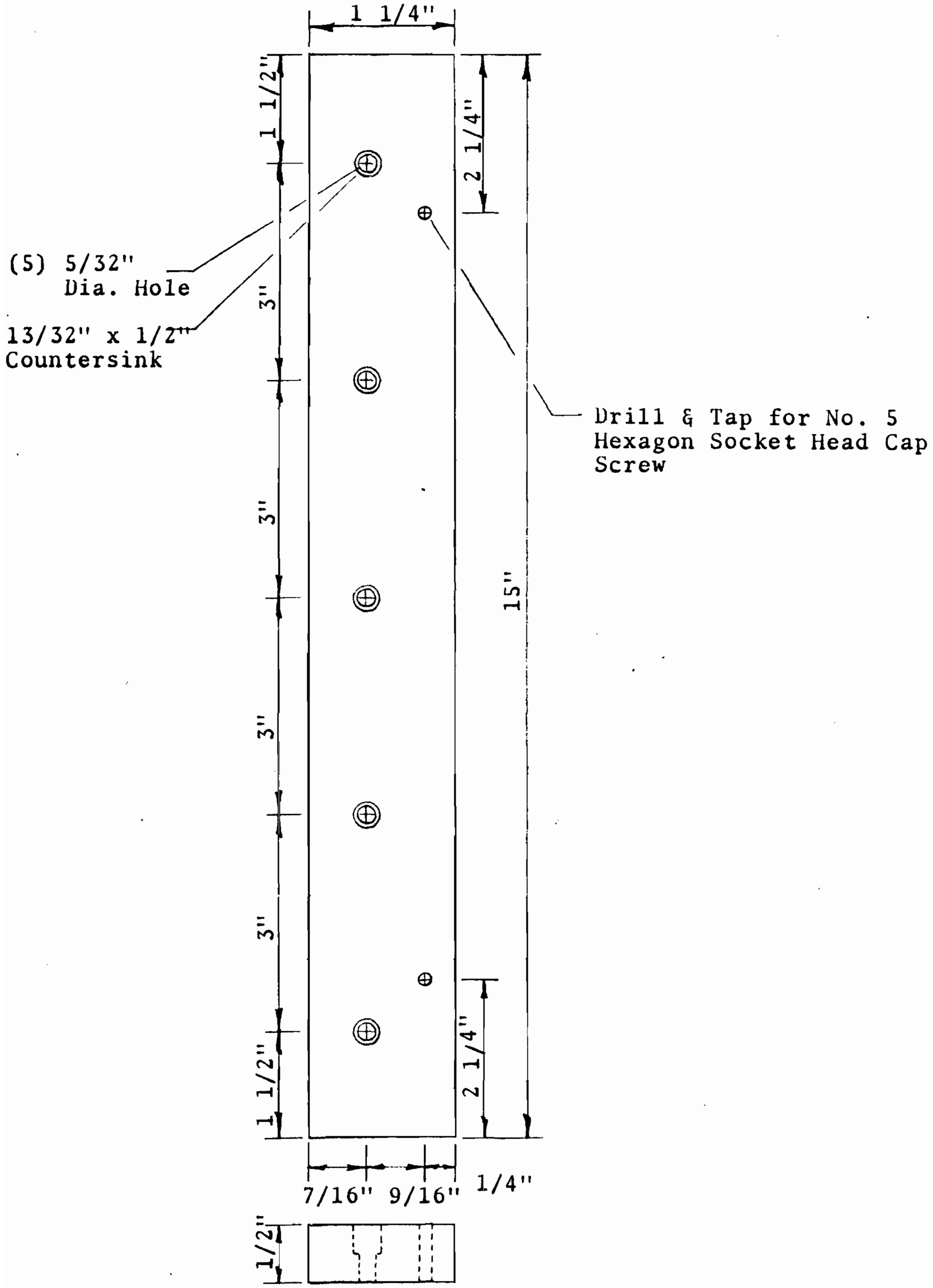


FIGURE 25. VERTICAL GUIDE FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST FIXTURE

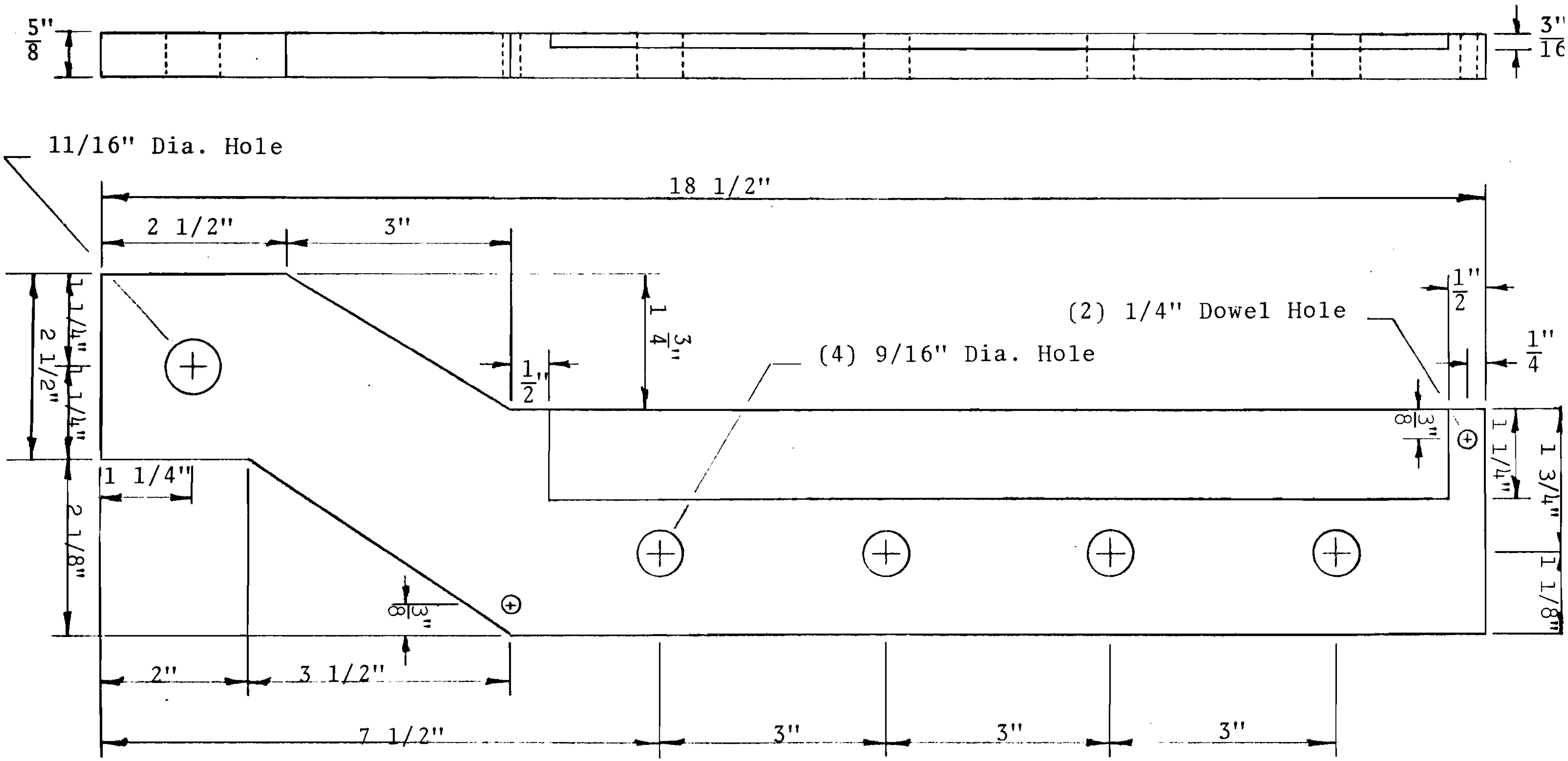


FIGURE 26. BOTTOM SHEAR PLATE FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST FIXTURE

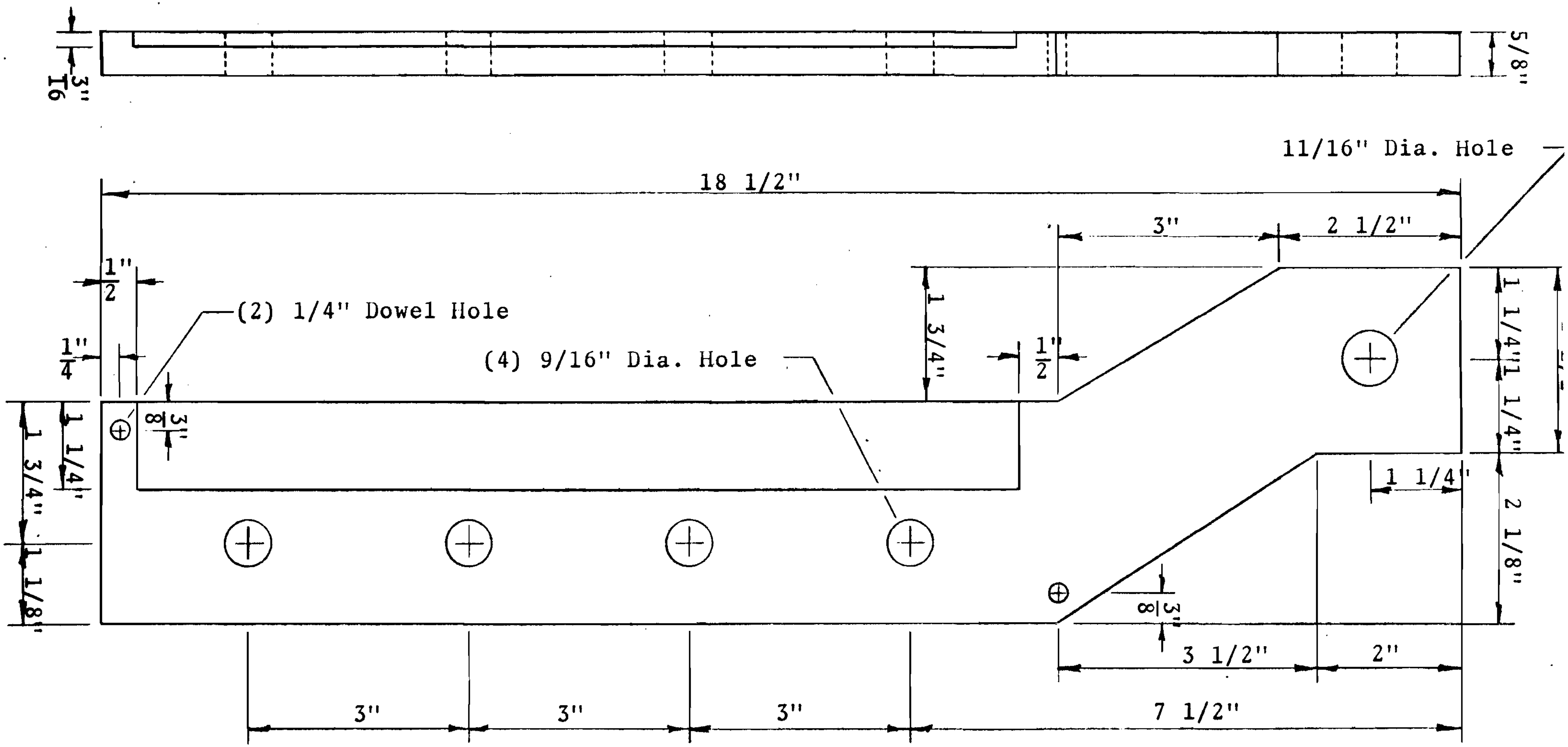


FIGURE 27. TOP SHEAR PLATE FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST FIXTURE

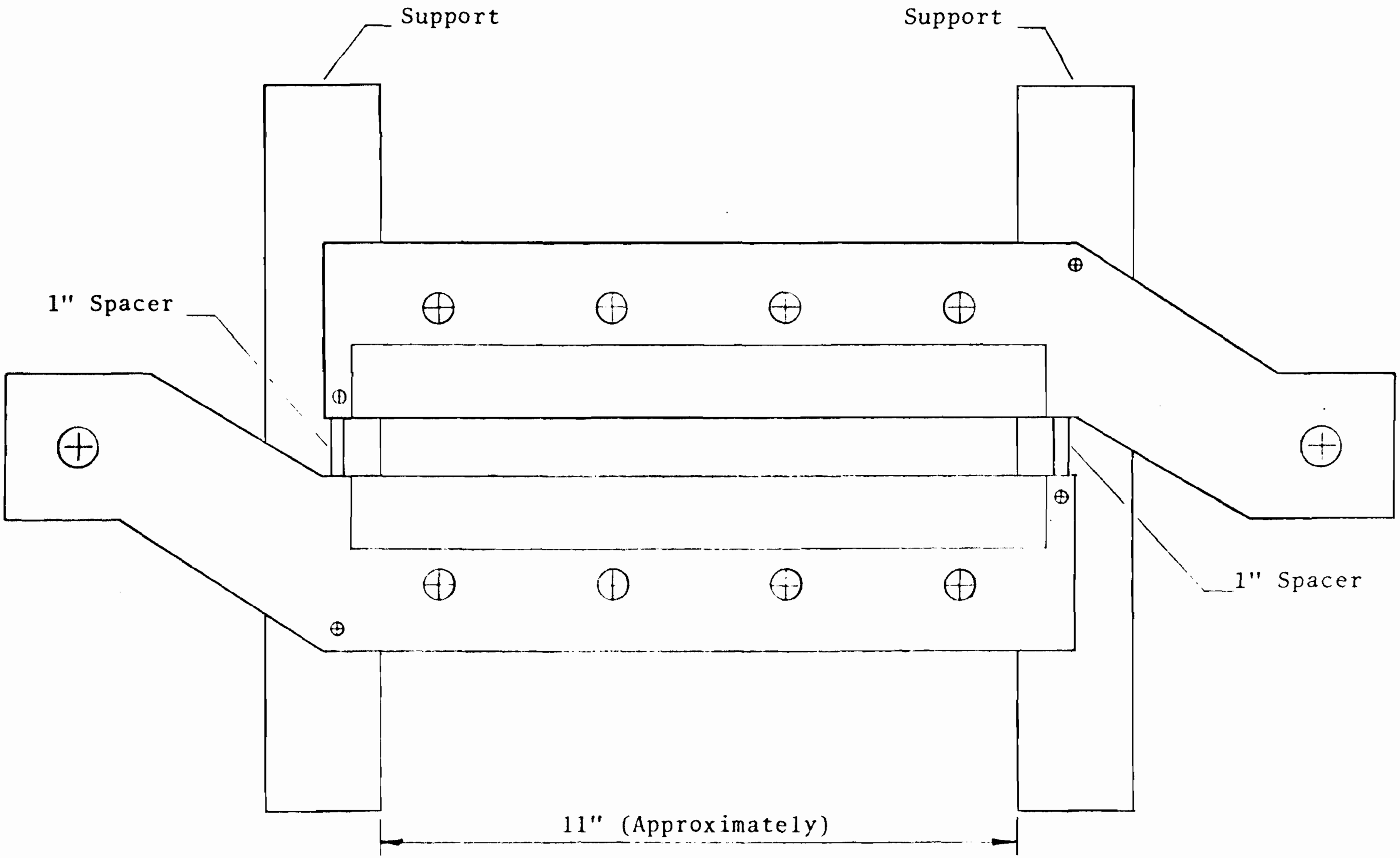


FIGURE 28. PLACEMENT OF BOTTOM SHEAR PLATES FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST

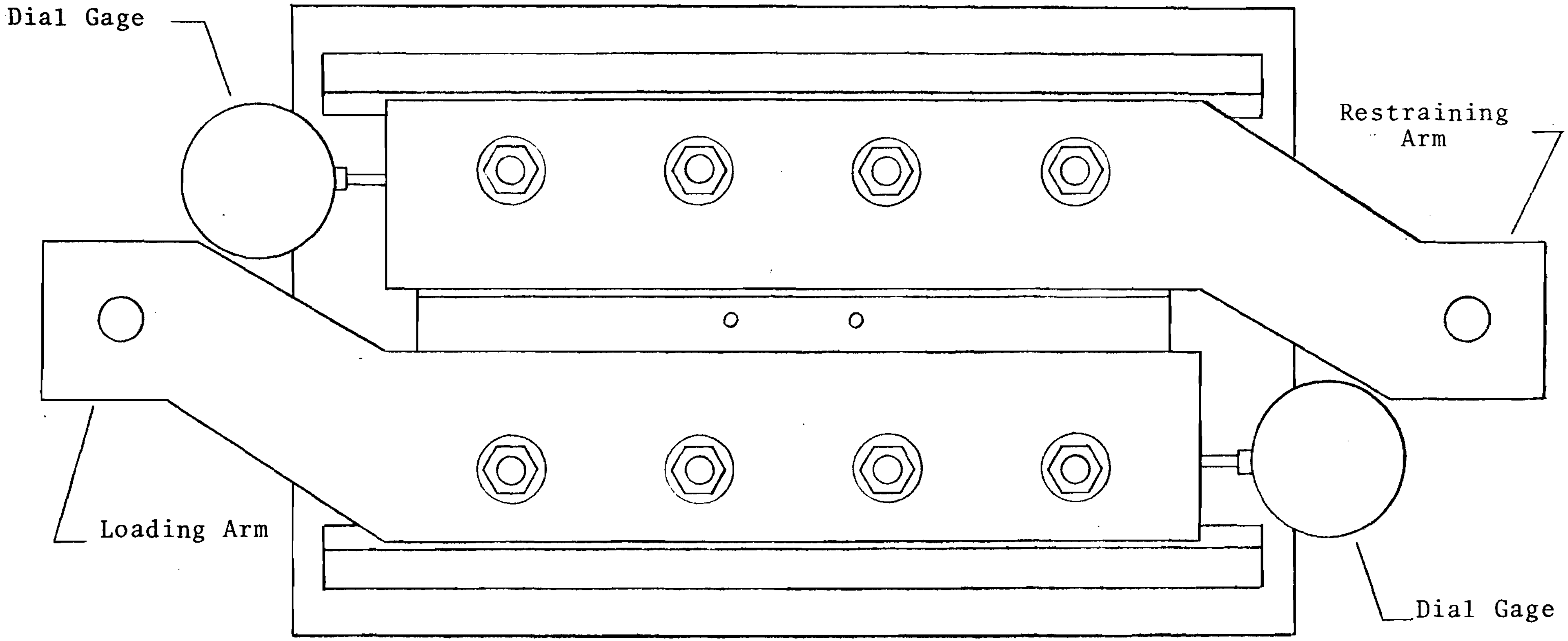


FIGURE 29. DIAL GAGE LOCATIONS FOR SINGLE-SHEAR (SIMULATED DIAPHRAGM ACTION) TEST